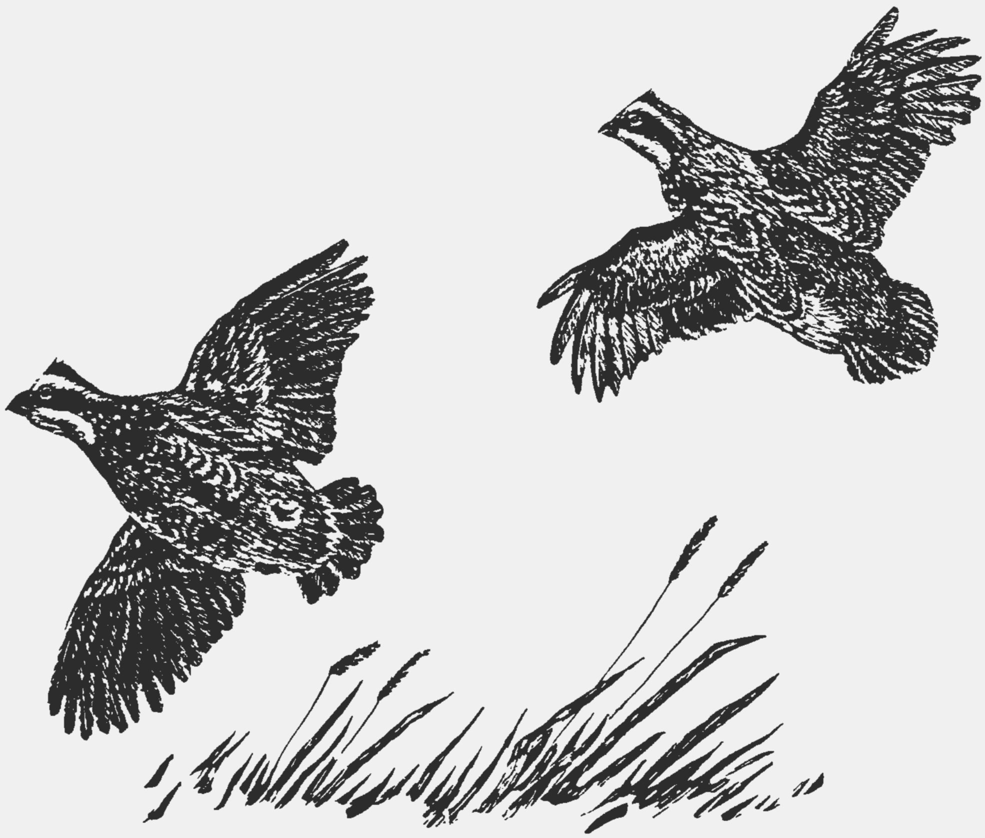
PROCEEDINGS
SECOND NATIONAL
BOBWHITE QUAIL SYMPOSIUM



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Stillwater, Oklahoma

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*Invited papers.

PREFACE

The original objectives of the organizers of this symposium were "to provide management biologists, research biologists, administrators, sportsmen's organizations, and interested lay people an opportunity to interchange information related to management of the bobwhite quail; to bring together available information concerning status, research programs, managememnt activities, and land use trends affecting bobwhites; to present a forum for discussion of interstate and inter-agency planning for management of bobwhites; and to focus attention on bobwhite quail through release of information to the general public in symposium proceedings, news releases, and feature articles." We did not reach as many lay people as we would have liked; however, plans are already underway for a National Quail Symposium, which will more actively involve laymen.

Papers in this volume address a number of issues including rapid deterioration of bobwhite quail habitat, effects of disease, effects of environmental toxicants, harvest patterns, effects of land management practices, and other quail management techniques. There are those who believe that no more bobwhite quail research is needed because we already know all we need to know about bobwhite quail management. However, as some of the symposium papers point out, our information is not current. Studies conducted 20 or 30 years ago apply only to conditions of 20 or 30 years ago. Both environmental and social conditions are changing rapidly in the United States; our research techniques, data base, and management techniques must keep up with current conditions.

QUAIL HUNTERS' FIELD EVENT

On September 13, the first day of the symposium, a Quail Hunters' Field Event and Barbecue was held at Lake Carl Blackwell. We would like to thank the following individuals for their efforts in making this event a success:

Chairman--R. W. (Bill) Altman

Master of Ceremonies--Fred J. Oliver

Committee--E. B. Epperson, John Floyd, Howard Jarrell, and Delmar Smith

Participants--Delmar Smith, Bill Trabue, John Floyd, E. B. Epperson, Howard Jarrell, Rick Smith, Tom Smith, Terry Townsend, Mary Townsend, Dr. Gary Miller, Irvin Bollenbach, and Fred Oliver.

BOBWHITE QUAIL AND CHANGING LAND USE

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Abstract: The downward trend of bobwhite quail (Colinus virginianus) numbers nationally is well established. Generally, this reflects deterioration and widespread loss of suitable habitat resulting from changes in land use. Since the 1940s research on the quail seems to have dwindled with few indications of on-going studies. There is much emphasis on setting aside areas as wilderness and natural areas and creating special funds, but these activities cannot accommodate the special needs of quail except in a general way. The intense emphasis on the economics of agriculture, use of chemicals in farming, and the activities of government and agricultural colleges have all but eliminated wildlife and diversity in many rural settings. Seemingly, a plausible course of action includes best land-use practices in concert with special programs of habitat development and preservation, an intensive effort to develop public awareness and support, the establishment of continuing long-term studies in connection with research-demonstration, a re-emphasis on well-trained field biologists with specialty in bobwhite ecology, a greater quail habitat management emphasis on public-controlled lands, a vastly improved and effective cooperation by various state and federal agencies, and carefully-planned and regulated land use for major soil types and/or ecosystems.

According to the geologic record, bobwhite quail (Colinus virginianus) have been around possibly a million years. However, because of the long periods of given dominating vegetation types, it is probable that prior to intrusions by man numbers were few and populations widely dispersed, being associated with the boundaries and "breaks" in vegetation types of major ecosystems. The absence of bobwhites in middens in its probable range suggests other forms of animal foods were more readily available and/or desirable; possibly its small population was an important factor. With the activities of the resident Indians, local patterns of vegetation were altered; these alterations probably represent the first enhancement of quail habitat that was not due to elements of weather. The story of the settlement of our country is well documented; and the increment in quail numbers, beginning with vigor about 1800, seems a consequence of the settlers' land-use practices. Abundance throughout its range seemingly prevailed until the mid-to-late 1800's followed by varying degrees of stability until the mid-20th century when declines became well documented. One can theorize that this pattern of population growth and decline exhibits the bobwhite's "fit" in ecosystems reflecting disturbance by man and an affinity with intermediate successional vegetational events rather than pre- and post-subclimax stages intertwined in the mesh of diversity. This accommodation to habitat by quail should yield unique and productive management possibilities, as such vegetational conditions are more readily man-enhanced than are the pre-and post-subclimax stages. Unfortunately, as we now well know, the intermediate phases of succession are likewise the most attractive in accommodating man's many needs for food and fiber. Efficiency (money, time, and energy) of the immediate does not contribute to the long term; but, more important, it does not recognize the significance of natural events in an ecosystem nor does it identify values not readily deposited in the bank.

The trend in quail populations nationally, recognizing local exceptions, is downward and with an ever-increasing pace. A legitimate question is are we at a point of no recovery; is this bird on the way out in major portions of its range? To what extent can we retard (or maybe stabilize at a given point) the deterioration of habitat and hence the quail's demise? I wish I could be optimistic in response to these as well as other similar questions for quail and many other species that occupy successional stage habitats. It is my intent to examine several aspects, to "crystal ball" a bit, and to offer some thoughts regarding the future of the bobwhite. Do know there will not be apology for a gloomy picture and the critical views expressed; facts of support are abundant and widely known by biologists throughout the quail range. You will note, of course, a Midwest orientation throughout, but there is reflected nearly 37 years of interest and study.

Examination of the literature on the bobwhite suggests that we have either considered, by in large, that there is no more to be learned about this important bird or we have, in general, given up hope that anything can be done to improve its status. The 30's through the 40's seemed a peak in the production of research and management papers and bulletins; indexes and federal aid documents suggest a reduced emphasis from 1950 to 1970 and that few states are currently studying the bobwhite. This seeming apathy is a disgrace to our profession; will we get excited when the bobwhite appears on the threatened or endangered lists? I recognize possible reasons for this, as generally monies are used for the "quick and dirty," the short-term effort for answers wanted yesterday. Also, there is a prevailing opinion that we can treat management practices generally and this will benefit the bobwhite as well as many other species. Such is only lip service unless the quail is the focus of these efforts. I personally find little comfort in most planned land use programs currently practiced on public lands as the quail is really not addressed; seemingly, the motivation is how many people can be accommodated. I suspect that it is hoped that some good will be contributed; some may be, but it will not be much.

Activities, as few as they are, in studying and in managing habitat for quail are too little, possibly too late in many cases, for too big a problem. States generally are beating "spot fires" and not addressing the roaring inferno which is consuming habitat everywhere. There is much evidence of grasping for any option, good or bad, hoping for the impossible. We are seemingly driven to grasp for any "flicker" to suggest we are doing something, but we never really come to grips with the fundamental issue of habitat loss. The identification of public or private land as wilderness, natural areas, nature preserves, special management units, etc., has its PR values; and it reflects an important effort. But we are kidding ourselves if we believe anything more than a 3-inch bandaid is being applied to a 30-inch incision. Do we really understand that these are largely last-ditch efforts to avoid complete loss of components of our environment? Further, that which offers hope for one state or region, one species or group of species, one habitat type or another, may have little utility generally because of different types of land uses now and in the future; but, more important, the future of such efforts may be questionable anywhere. We have tunnel vision and have a strong inclination to follow (or grasp for) almost anything initiated anywhere; Colorado is not Iowa nor is Florida Oklahoma. We move to generate a variety of special funds for a great many activities, requesting the support of legislators and the public, because problems will be resolved. Please remember that the crisis of the drouth and depression of the late 20's and early 30's provided a national soil conservation program which yielded outstanding data on how we could use our land for a wide range of integrated and interactive interests without serious impact on its resource base. Now 50 years later and after the allocation of 25-30 billion dollars of enticements, a much worse situation exists than in 1932. A large part of that soil erosion problem and the enlargement of the State of Louisiana are due to the destruction of bobwhite quail habitat. No, I am not opposed to tapping many sources of funds or generating new revenue, but let us not be lulled into dreaming that this answers the real question of statewide habitat loss on private holdings. Further, don't reflect on accomplishments of the waterfowl stamp when thinking about upland species. Much of waterfowl management is "barnlot" animal husbandry; the bobwhite can be "crowded" only in propagation units located in one's backyard or government-operated game farms.

Over the years, programs to restrict crop production, namely feed grains in the Midwest, have come and gone; most offered little as habitat improvement for quail because of management practices designated for such acreages. However, should retired acres reflect a continuing program and there be opportunity and encouragement for wildlife habitat development and management, opportunities to "replace" quail habitat in certain regions are a possibility. But the likelihood of such occurring in the face of farm economics as related to the world markets and the GNP syndrome of economic strangulation seems remote. Further, even if such a hope became a reality, we cannot presume that travel lanes, fallow fields, and rotation farming will appear in those areas regarded as prime and high capability farm lands. Hence, banked or retired lands will occur only in very limited regions within a great portion of the quail range. In many cases, these will be "island" populations subject to intense pressures if hunted because they have no place to escape. But, this is surely better than nothing and probably can be appropriately managed if it is addressed by responsible administrators.

Nearly every thought over time, with regard to management of quail in an agricultural community, is without feasibility today except that there be a sacrifice by the farmer. We have not been able to sell because generally sales pitches did not address the real world. Farming is a business and no longer an activity which simply reflects a life style of the non-urban setting. To be successful, it reflects efficiency, but no longer as a self-contained unit. Because farming today is totally dependent on an enormous array of interactive processes that impact its fate as a business, it is an inescapable part of an entanglement which does not permit much thought and concern for wild animals. Appreciate one can no longer hear the sounds of wildlife or have time to reflect on seeing the first quail chick of the season; after all, the tractor is too noisy and the operator rides in a sound-proof air-conditioned cab, it moves too fast and requires one's undivided attention, and it shows no response to curses, gee and ho, or a loving pat when the day is done. What we know to be in the best interest of quail today is as unacceptable as are unoccupied units in a condominium. To add "quality of life" to either setting requires higher rents. Increased short-term costs cannot be afforded either by the business effort or the consumer, and there is no motivation to contribute the luxury of diversity because its importance is not appreciated.

One must raise the question as to how and to what extent can we retard the deterioration and loss of quail habitat. The answer is only to the extent that a fluctuating status in land use can be accommodated that yields a variety of stages of early to mid plant succession, and/or permits incorporation of selected habitat management into land use programs that will yield profits for the farming enterprise. I see but one way to accomplish some of this, and that is through a variety of activities that focus on identification of best land use practices for major soil types. But there will be no progress in this direction without massive change attainable only through directed, coordinated efforts. Such progress requires the impact and support of continuous research and demonstration, educational institutions, legislation, elected officials, government administrators, professional societies, and the public in general. Is this a "cloud nine" perception? Yes, but we have the capability to marshal such togetherness as demonstrated by World War I and II. Although the nuclear age may prove otherwise, no civilization of record has been lost because humans could not get along. The record suggests that abuse of land (soil), and environment generally, was the real cause for the demise of 20+ civilizations. What are our excuses for not rising above this mentality? There is insufficient time for me to develop this issue now.

Let me address in more detail some of the matters I've identified and explore, and possibly evaluate, a selected few of the partitioned and disjunct efforts to enhance our environment.

(1) There are many ways habitat for quail can be improved if we do nothing more than emphasize best use and management of land in accordance with known prescriptions tried and proven over 50 years ago. This emphasis will not result in the "good old days," but it will be a major contribution especially when complemented by those efforts to delineate areas through lease, agriculture retirement, acquisitions as preserves and wilderness, etc. One cannot over-emphasize the dangers of isolation and the fragility of island populations due to the vicissitudes of weather, disease, parasites, predators, or competing organisms.

It is conceivable that the seriousness of soil erosion could result in a blessing. However, this will occur only if the public in general and government everywhere recognize the disaster of the alternative, that is to ignore the problem. Consider the contribution of strip-cropping, contouring, windbreaks, developed drainageways, retired acreages of permanent cover to protect marginal sites, and maybe even some small degree of crop rotation. I see little chance, however, to change importantly the trend to larger field size, specialty agriculture, and monoculture. Clearly, the opportunity for extensive diversity reflecting the right vegetational mix is not great, but there is offered an opportunity and challenge that are in the right direction.

(2) Public awareness, but especially understanding and undiluted support, are required to address the problems at hand if there is to be change. The 50's and early 60's reflect a period of progress in this direction via training of teachers and classroom instruction. But, for a variety of reasons, largely related to apathy by school administrators, legislators, school boards, and teachers, this has dwindled significantly. Further, Agricultural Experiment stations, which in theory operate at the "cutting edge," have become the victims of chemical companies and Washington bureaucracies. In addition, the U.S. Department of Agriculture, with its tentacles in essentially every county in the United States, has willfully ignored the necessity for best land use, including a commitment to fauna and flora, because of the tiger it has by the tail, namely GNP as it relates to the economic health of agriculture. The Soil and Water Conservation District, an admirable effort at democracy and volunteerism, is the recipient of this long intestinal tract, which originates in Washington and which is "tributaried" largely by those who dare not address the real issues or tell it like it is. One might rationalize that Agricultural Experiment Stations could offer a "freedom road" out of this intellectual strangulation. But examine their track records via publications, extension programs, etc., the last 25 years. Do you find exception to the emphasis on chemicals, intensified land use, more acres taken from other important uses, continued promotion of the greatest cause of cancer, etc., as <u>the way</u> to increased crop production? Despite air, water, and soil being our essential life supports, these are treated as products of nature to be exploited; or, how much can one get for the least investment of time, dollars, and energy in the shortest time span. Is it any wonder that wildlife such as the bobwhite has been ignored, considered irrelevant in the scheme of things?

(3) We have no alternative but to re-establish essential habitat if there is to be maintenance and/or increase in quail numbers and their distribution. The widespread loss of premier habitat has had an insidious effect because previously less important factors now are critical. Individually and/or collectively factors such as severe weather, predators, crop harvesting, hunting seasons, chemicals, etc., once easily absorbed by quail populations, are now readily identified as seriously reducing populations. Often recovery from these problems is slow at best, if at all. As a result of these factors being identified as suspect, we lose proper perspective of the annual needs of quail and now focus on the individual items for resolution. Never before has the necessity for long-term studies, research-demonstration areas, and organized efforts of well-trained quail

biologists been so important. We monitor annual harvest levels and hunter success and bemoan the plight of those who buy a license. And we continue our presumption that we know all that needs to be understood regarding quail. How many state departments have on-going research that will identify the situation today? By default, we imply satisfaction that the invaluable work of Herbert Stoddard and several others representing a 3-decade period (1930-60) is in total applicable to current problems in the quail range. Does this represent an appropriate sensitivity for a research or management biologist?

Generally, we have no real understanding of the subtle happenings because we have not followed in detail leads identified years ago. Do appreciate the minuscule factors of yesteryear are the determinants today. We are no longer "living high on the hog"; the opportunity to endure risks with this unique bird is long past. Because of recognition of the importance of bits and pieces of biology as they apply to the whole, we developed the systems approach. Unfortunately, most of us are "hungover" with blackboard diagrams and have not been able to really sell the end product.

(4) Never before has there been such a necessity for the organized efforts of well-trained quail biologists to study and manage this outstanding bird. The true quail hunter can identify quality quail habitat and is reasonably successful in hunting because of this. I would judge that many biologists who have been employed in the last 15-20 years do not have an equivalent perception. This is in part because many states and universities have not focused on quail because of a lack of available support for and interest in its research. But, in large part, pressures of the new approaches to research, data analysis, and management sermonized in governmental and academic circles (program management systems [PMS], management by objectives [MBO], habitat evaluation procedures [HEP], etc.) have yielded prospective employees who are in large part mechanics, engineers, or technicians. Disgraceful as it may seem, thinking, philosophizing, and theorizing are passe unless the thoughts can be put through a computer and to the test of elaborate formulae that are readily fabricated if they don't fit. Unfortunately, in our efforts to be "definitive" and "sophisticated," both very noble and worthwhile objectives, we have forgotten that these are simply gimmicks, tools if you will, and will not, cannot, help us "think like a quail." Please, I am not negating the value of sophisticated methods in research and management. But I am truly ashamed and thoroughly embarrassed when our students and members of our profession can spout all sorts of technological terms, cover blackboards with formulae, and discuss all sorts of "packages" for computer analysis, yet not have the slightest notion of what it means in terms of quail biology. We must have both the highly qualified field biologists and the technical genius; but if I could have but one, it would be the former, who could think, whistle, and enjoy springtime like a quail.

(5) I believe there is opportunity to improve greatly bobwhite management practices on public-owned lands; however, public-owned lands suitable for bobwhite habitat range from little to few in terms of acreages in different states. Also, they usually show maldistribution on a statewide basis and hence are often considered unimportant and not useful to segments of the human population. More important, the fact that individual holdings are often too small to be effective as management units needs to be reconciled. A greater effort by federal agencies, especially in national forests and refuges, could yield important returns in given states. But there must be attitudinal changes to accomplish a more responding climate and responsible action, as many such holdings tend to focus on either a singular or multiple mission, neither of which has much to offer high-quality quail habitat.

Also associated with public holdings is the question of opportunities to hunt quail. Even if maximum habitat management is exercised, number of hunters benefited is often small at best. Further, to provide a good experience is immensely difficult unless hunting is restricted so as to avoid disruption of routine quail behavior patterns. This offers little in the long run, may be a questionable use of funds, and will not generate much hunter support. As unpalatable as it appears to many here, in some states particularily, production of high-quality birds and their release at well-planned intervals on properly-managed sites (habitat and hunter) may be justified. Obviously the cost of such an effort cannot be adequately subsidized by conventional hunting license fees.

(6) Although not significant in providing acres for quail, full and effective cooperation between state and state, state and federal, and federal and federal agencies can contribute much to public interest and understanding of proper resource management generally and the plight of the bobwhite quail in particular. Currently, much collaboration is lip-service and more times than not reflects indifference to antagonism. Although much of this is nothing more than "defense of turf," it is surely not in the best interest of the public dollar or the bobwhite. The opportunities to work with private interests and enterprises are structured in almost every government program, and few segments of the public are immune to the impact of one or more of these. Yet, one fails to see much that suggests coordinated coercion and leadership by responsible government agencies to ensure the best for the land resource and its occupants. Is there not a common ground and interest?

(7) Finally, I wish to address the question as to whether there will ever be accepted philosophically regulated land use in the rural setting. Will we ever establish by policy required practices for handling major soil types and ecosystems? Many believe this the only approach that will provide opportunity for diversity in our life and, in turn, enhance the bobwhite quail. But at what level will success in

our efforts occur when there seems to be no exception to the bobwhite being a dispensable "by-product" of all other dominant or primary uses of land? If it's the "meat market" we wish to contribute to, appreciate the quail is but a delicacy and its rearing is easily accomplished in 1-2 acres of space.

LAND USE AND BOBWHITE POPULATIONS IN AN AGRICULTURAL SYSTEM IN WEST TENNESSEE

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Abstract: The efficacy of a computer assisted habitat evaluation system (IMGRID: Information Management on a GRID cell system) was tested on Ames Plantation in west Tennessee. Habitat characteristics and bobwhite (*Colinus virginiana*) population size were compared to delineate the effect of land use changes on bobwhites. Significant changes in land use occurred. Pastures decreased from 120.4 ha in 1966 to 35.0 ha in 1980, while soybeans increased from 102.4 to 193.1 ha. Idle land decreased from 212.9 ha to 178.6 between 1966 and 1980. Bobwhite population size was negatively correlated with the area maintained in soybeans (r = -0.63) and positively correlated with pastures (r = 0.76) and idle land (r = 0.76). Multiple component analyses indicated highest use by bobwhites of (1) areas where idle land, forests, and agriculture came within close proximity, (2) areas near food plots, and (3) idle land alone. Single component analyses identified high use by bobwhites of idle land, wild herbaceous vegetation, and food plots. Within forests or idle land, bobwhites preferred areas containing honeysuckle.

The quality of habitat is one of the most important factors influencing the fate of many wildlife populations today. The importance of habitat necessitates developing a suitable, comprehensive system of habitat evaluation. Such a system should be capable of identifying critical components of habitat and forecasting the effects of manipulating these components. It would be useful for determining a site's potential for wildlife as well as being a predictive tool for wildlife managers.

Originally, analyses of habitat features were facilitated through observation of aerial photographs or cover maps (Dalke 1937, Graham 1945, Arnold 1946). Recent research has broadened the scope of these early works with some success (Hanson and Miller 1961, Burger and Linduska 1967, Baxter and Wolfe 1972, Schuerholz 1974). Computer technology has enhanced the sophistication with which habitat and population data can be stored and analyzed.

Many computerized geographical systems are currently available that could accommodate diverse types of wildlife data (Wilcott and Gates 1977, Brooks and Pease 1978). One such system, IMGRID, has been tested by the Tennessee Valley Authority (TVA) and the Tennessee Wildlife Resources Agency (TWRA) on the Catoosa Wildlife Management Area (CWMA) (Davis 1980). Although extensive work has been done on the CWMA, with a promising outlook for IMGRID, the majority of the habitat analyses have been for relatively large, wide ranging species such as white-tailed deer (*Odocoileus virginianus*), European wild hogs (*Sus scrofa*), and eastern wild turkeys (*Meleagris gallopavo silvestris*).

IMGRID appeared appropriate for use on the Ames Plantation in west Tennessee. During 15 years of quail research, bobwhite densities and concurrent habitat conditions have been recorded. This project investigated the merits of using IMGRID for delineating relationships between various characteristics and bobwhite populations.

We would like to thank the staff of the Ames Plantation for their assistance, particularly Dr. James Anderson and Alan and Becky Houston. We also appreciate the support and assistance of certain TVA staff, particularly Stanford Davis. Significant financial support was provided through McIntire-Stennis funds. We also acknowledge the use of The University of Tennessee Computing Center, Knoxville, Tennessee.

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STUDY AREA

Ames Plantation is the site of the National Field Trial for pointing bird dogs. An 832.5 ha tract within the plantation, designated as the Morning Field Trial Course (MFTC), was used for the study. Loess soils, consisting of the Loring, Grenada, and Calloway series, averaging 1-3 m in depth and overlying Coastal Plain marine sediment, predominate on the area (Flowers 1964). Topography is moderately dissected to gently rolling; average altitude is 135 m (Flowers 1964). The growing season averages 210 days. Average annual precipitation is about 135 cm. The yearly average temperature calculated by Eubanks (1972) from U.S. Weather Bureau (1966, 1967, 1968, 1969) data is 16.4 C.

The MFTC is highly agricultural, with extensive areas planted to soybeans. It is intensively managed for bobwhites. Since 1966, bobwhite populations have fluctuated greatly, from 3.8 birds/ha in December 1972 to 1.4 birds/ha in March 1980 (Table 1).

Table 1. Census data from December and March censuses, 1966-1980, on Ames Plantation in west Tennessee.

Month	Year	Number of Coveys	$\bar{x}$ Birds/ Covey	Total Number Birds Found
March (Pre-breeding)				
	1967	76	12.2	925
	1968	81	13.2	1,023
	1969	82	12.6	1,033
	1970	66	12.6	832
	1971	77	12.5	964
	1972	95	13.0	1,269
	1973	85	11.8	983
	1974	62	11.0	681
	1975	61	10.3	637
	1979[a]	61	10.9	701
	1980	50	11.4	573
Mean		72.4	12.0	879
December (Post-breeding)				
	1966	90	13.1	1,184
	1967	101	14.6	1,478
	1968	108	13.9	1,505
	1969	73	13.8	1,077
	1970	89	13.2	1,179
	1971	111	12.0	1,334
	1972	111	14.3	1,587
	1973	93	12.3	1,145
	1974	66	13.8	847
	1976[a]	72	12.3	897
	1977	83	13.3	1,101
	1978	65	12.0	782
	1979	62	11.9	736
Mean		86.5	13.0	1,142
February[b]				
	1980	59	10.2	663

[a]Populations not censused during March 1976-1978 or December 1975.
[b]Additional census made in 1980.

METHODS

Aerial photographs were standardized to produce scaled maps of the study area for 1966, 1971, 1975, and 1980. An acetate grid, with grids representing 1.0 ha, was overlaid on these maps. Various components of habitat specifically identified with the aid of field maps were numerically coded in their respective grid cells for use by IMGRID. Bobwhite census data were also encoded for correlation with habitat types.

General land uses were consolidated into categories: agriculture, pasture, wild herbaceous vegetation, idle land, and forests. The three most abundant cover types in each grid cell were encoded, each into a separate data element (mutually exclusive sets of information that describe a resource or land use unit, e.g. soil mapping units, forest types, etc.) (Beeman 1977). Numerical values were arbitrarily assigned to these components in such a way that IMGRID could later detect the various combinations of habitats in each grid cell.

During 1980, information on honeysuckle, forest types, herbaceous vegetation, and land use was collected in the field at a higher resolution (grid cells represented 0.25 ha) for a more detailed evaluation of specific use patterns. Samples of honeysuckle were collected, dried, and weighed to identify representative stands of honeysuckle. Plots were subsequently categorized in terms of density as Absent, Low (0.1-250 g/m^2), Moderate (251-500.0 g/m^2), or Abundant (more than 500 g/m^2).

The data collected at the 0.25 ha grid cell size were generally encoded as ranked values representing specific data entities. For example, the data encoded for the forest type data element were the following:

Data code	Forest type
00	None present
01	Seedling pine
02	Seedling bottomland hardwood
03	Seedling upland hardwood
04	Cedar
05	Pole sized pine
06	Pole sized bottomland hardwoods
07	Pole sized upland hardwoods
08	Sawtimber pine
09	Sawtimber bottomland hardwood
10	Sawtimber upland hardwood

A planimeter was used for 1980 data to calculate the area maintained in each habitat type. IMGRID was also used to assess the composition of habitats. T-tests were then used to compare IMGRID's estimates to those calculated by the planimeter.

Mean population estimates were derived for the years 1966, 1971, 1975, and 1980 (Table 2). Patterns of land use were then regressed with the mean populations to correlate land use patterns with population size.

Table 2. Classes of average populations of census data from Ames Plantation, surrounding the years from which IMGRID habitat data were available.

Category	Census	Population Size	Average Population
	December 1966	1,184	
	March 1967	925	
	December 1967	1,478	
	March 1968	1,078	
	December 1968	1,505	
	March 1969	1,033	
1966			1,200.5
	December 1969	1,077	
	March 1970	832	
	December 1970	1,179	
	March 1971	964	
	December 1971	1,334	
	March 1972	1,269	
	December 1973	1,587	
	March 1973	983	
1971			1,152.8
	December 1973	1,145	
	March 1974	881	
	December 1974	847	
	March 1975	637	
	December 1976[a]	897	
	March 1977[b]	681.7	
1975			814.8
	December 1977	1,101	
	March 1978[b]	836.7	
	December 1978	782	
	March 1979	701	
	December 1979	736	
	March 1980	573	
1980			788.3

[a]December 1975 and March 1976 censuses were not performed.
[b]Average survival ($\bar{x}$ = 0.76) from December to March was calculated for all other censuses to obtain the estimated March population.

IMGRID keywords were used to overlay habitat features with census data for 1966, 1971, 1975, and 1980 to detect trends in habitat use. These trends were analyzed using two techniques, multiple component analysis and single component analysis.

The multiple component analysis permitted the identification and delineation of the interactive effects of important combinations of habitats. Habitats were categorized as pasture, idle land, forests, food plots, and agriculture. The three major habitat components of each grid cell were recognized; 25 possible combinations of habitats existed. The percentage of grid cells with coveys was calculated for each of these combinations.

The single component analysis isolated individual habitat types, without regard to other habitats. For example, all grid cells with soybeans were located and those cells also containing coveys were delineated. This analysis permitted the isolation of all habitat types present during each year.

Chi-square tests were used to detect differences in habitat use in every census for both analyses. Chi-square tests detected differences in use but not the location of these differences. For this reason the percentage of grid cells that contained coveys was calculated for each habitat type (Huntsberger and Billingsley 1977). Important habitats were identified as those exhibiting high percentages of use.

In some instances certain habitats or combinations of habitats from the IMGRID analyses exhibited an expected chi-square value of less than 1. These combinations were clumped into logical categories for analysis.

T-tests were used on December and March single and multiple component analyses for all years to test for a difference in habitat use trends between censuses. Since three censuses were performed in 1980, analysis of variance was used to test for different patterns of use during that year.

RESULTS

IMGRID accurately depicted the composition of habitat when compared with the area defined by a planimeter. Subsequent IMGRID analyses detected major changes in land use between 1966 and 1980 (Table 3). Pasture decreased from 120.4 ha (14.4 percent) in 1966 to 35.0 ha (4.2 percent) in 1980. Soybean production increased from 102.4 ha (12.3 percent) in 1966 to 193.1 ha (23.2 percent) in 1980. The total area maintained in idle land decreased from 212.9 ha (25.5 percent) in 1966 to 178.6 ha (21.4 percent) in 1980.

No differences in habitat use between December and March censuses were found for most years of the study ($P \leq 0.05$). For this reason censuses for each year were combined for analysis. In instances where there were significant differences between years, the censuses were analyzed separately.

Multiple component analyses indicated consistent use of certain habitat types throughout the study. These included grid cells with idle land only; grid cells with idle land, forest, and agriculture; and grid cells containing food plots. Pastureland was highly used during 1966 and 1971.

Single component analyses clearly illustrated that food plots were highly used. Idle land, areas classified as wild herbaceous vegetation, and fallow fields were also highly used.

The intensive multiple component analysis performed during 1980 indicated that edges of idle land and wild herbaceous vegetation were highly preferred. The intensive single component

Table 3. Composition of land use for 1966, 1971, 1975, and 1980 on Ames Plantation.

Land Use Type	No. of ha in 1966	No. of ha in 1971	No. of ha in 1975	No. of ha in 1980
Pine	55.4	53.8	68.8	64.2
Hardwoods	249.3	243.0	237.8	243.9
Fallow Fields	78.7	----	20.9	10.8
Food Plots	16.3	14.9	19.8	9.2
Lespedeza	----	23.3	2.2	38.3
Corn	29.6	25.0	11.6	70.1
Soybeans	102.4	181.7	168.0	193.1
Ponds	4.8	3.8	3.3	4.3
Idle Land	129.4	189.2	169.5	163.5
Cotton	48.1	29.3	30.8	----
Pasture	120.4	56.5	52.3	35.0
Milo	----	3.8	6.1	----
Wheat	----	16.5	17.6	----
Alfalfa	----	5.3	2.2	----
Hay	----	4.3	----	----
Field Peas	15.8	----	----	----

analysis for 1980 also defined idle land and wild herbaceous vegetation as the most highly used habitat types.

Additional IMGRID analyses for 1980 data found grid cells with honeysuckle to be preferred over those without. A moderate (251 g/m2 - 500 g/m^2) density was favored. Bottomland hardwoods were the preferred forest type, and idle land or forest types with honeysuckle were preferred covey locations.

The area maintained in row crops was not highly correlated with bobwhite populations. However, as soybean acreage increased, bobwhite numbers declined ($r = -0.63$). The amount of idle land ($r = 0.76$) and the amount of pastureland ($r = 0.76$) were positively correlated with the number of bobwhites on the study area.

DISCUSSION

Soybeans are a preferred food source on Ames Plantation, and they provide excellent habitat for bobwhites throughout much of the year (Eubanks and Dimmick 1974). However, harvested soybean fields provide no protection for bobwhites during critical winter periods. Use of soybean habitat was highest during the two years in which acreage was lowest. During the two years in which soybean acreage was greatest, the most highly used habitats were those supplying cover, such as fallow fields, wild herbaceous vegetation, and idle land. By 1980, 23.2 percent of the MFTC was planted in soybeans, much of this in large fields. These large expanses of soybeans replaced large idle fields and permanent pastures, perhaps creating shortages of necessary winter cover.

Idle land was consistently one of the most highly used habitat types. Idle land characteristically contained herbaceous vegetation often accompanied by dispersed hardwoods. These conditions provide ideal situations for quail (Klimstra and Roseberry 1975, Roseberry et al. 1979). Idle land and forests were major sources of winter cover. The decline in idle land has resulted in fewer favorable covey headquarters as defined by Yoho and Dimmick (1972). As a result, bobwhites have shifted to forests for winter cover. Forests were not highly used by bobwhites for food on Ames Plantation (Eubanks and Dimmick 1974), and the widespread use of forests is nontraditional (Stoddard 1931:404, Murphy and Baskett 1952, Kabat and Thompson 1963:55, Casey 1965). High use of hardwoods indicates a shift in importance from traditional early successional herbaceous vegetation to closed overstory forests. Use of these marginal habitats is unfavorable for bobwhites.

High positive correlation of bobwhite populations with pasture is not normally expected. However, the pastures maintained on the MFTC in 1966 and 1971 were lightly grazed and, therefore, resemble old field habitat. High use in those years reflected adequate densities of herbaceous vegetation interspersed in some cases with food plots. Perhaps also important, but not derived from this study, these pastures provided excellent nesting habitat.

Food plots, although comprising a relatively few hectares, were important to bobwhites throughout the study. These plots were established in pastures that originally provided a lush growth of broomsedge (Andropogon virginicus) but were otherwise relatively poor sources of winter foods. These food plots were planted with soybeans but also contained vegetation that could have been classified as idle. As pastures were converted to soybeans, the importance of unharvested food plots persisted, but their usefulness was likely related to their provision of cover as well as for food. For these reasons, habitats containing food plots were represented as one of the most highly used habitats in every multiple component analysis.

The intensive multiple component analysis in 1980 showed idle land to be a part of the three most highly used habitat types. The intensive single component analysis showed wild herbaceous vegetation to be the most highly used habitat type; idle land was second. The importance of idle land has been discussed; its reduced acreage has increased its relative value. Wild herbaceous vegetation was identified only for the intensive 1980 analysis. It was used to describe areas of wild vegetation free from woody invasion. In other analyses, this category of vegetation was classified as idle or fallow. Because of the shift of importance to soybeans, wild herbaceous vegetation may become increasingly important.

The nature of the walk flush census may introduce bias into the interpretation of habitat use trends. The censuses may push birds into heavy cover and overestimate the importance of honeysuckle or dense cover. However, it is believed that increasing scarcity of these areas is limiting the quail population on the MFTC.

Use trends may not accurately portray the significance of some habitat types. Soybeans are obviously important to bobwhites on the MFTC, yet little time is spent feeding in soybean fields due to the ease in obtaining seeds. Therefore, walk flush censuses may underestimate the importance of soybeans. The various IMGRID techniques used for analysis minimize these kinds of biases.

MANAGEMENT IMPLICATIONS

Extrapolation of data on the relative composition of land use and trends in habitat use yielded obvious management implications. The most obvious change in land use was an overall shift to increased acreage planted to soybeans. In early years of the study, when populations were high, lightly grazed pastureland afforded excellent herbaceous cover, and a diversity of row crops was maintained. Subsequent changes in land use patterns were accompanied by marked declines in bobwhite numbers. Transition lanes between soybeans and hardwoods have been shown to buffer shortages of adequate cover and to be beneficial for bobwhites (Rosene 1969). Increasing borders of herbaceous vegetation on the periphery of strategic soybean fields should greatly improve overall conditions for bobwhites. Optimum vegetation density and composition of these borders would be maintained through periodic burning or plowing.

Diversity, the key to bobwhite management (Fimlott 1969), may be encouraged through establishing smaller irregularly shaped fields. These fields would create an edge effect and allow interspersion of desirable habitats such as idle land with herbaceous vegetation and hardwoods with honeysuckle.

The presence of well distributed nesting areas is a necessary ingredient of good quail habitat (Reid et al. 1979). Broomsedge, the primary grass associated with nest construction in west Tennessee, can be encouraged through timely plowing or burning. However, indiscriminant burning can cause destruction of potential nest sites and optimum densities of honeysuckle. Site specific management using IMGRID as coordinator could approach optimum densities, quantities, and the proper juxtaposition of soybeans and idle land with herbaceous vegetation and honeysuckle.

The maintenance of food plots in critical areas can supply necessary components of food or cover (Robel et al. 1974). Areas deplete of winter food supplies may be supplemented by productive food plots, while areas lacking winter cover will benefit from the protection of idle land in those food plots.

CONCLUSIONS

The IMGRID approach to habitat analysis successfully identified critical changes in habitat composition with respect to their impact on bobwhite population numbers. Obvious management implications emerged, though no revolutionary concepts for bobwhite management were developed.

Perhaps the most instructive (and surprising) lesson derived from our analysis was the negative impact of expanding soybean acreage on the study area, inasmuch as soybeans constitute the principal food of bobwhites on this area during winter (Eubanks and Dimmick 1974). This negative correlation, coupled with the positive relationships among populations, pastureland, and permanent idle lands, suggested to us that increasing the potential food supply failed to compensate for the corresponding dramatic reduction in security cover and possibly nesting cover. During the latter years of our study, soybeans were harvested completely, except in the fenced food plots, often as early as late October and early November, leaving large fields essentially barren of cover to the edge. The critical need for late winter food and permanent idle land for cover was highlighted in March 1981, when the population was at its lowest ebb in 15 years. Roughly 25 percent of the population was located in and adjacent to 10 food plots that occupied about 1 percent of the total area.

The usefulness of IMGRID for evaluating habitat quality on our area was limited by the large amount of manpower necessary to encode appropriate data. Technology now exists to moderate this problem, but significant habitat characteristics such as the presence and density of honeysuckle can not be encoded from aerial photos, requiring laborious field checking. Additionally, the nature of grid cell encoding limits the degree of specificity that can be used. This can reduce the accuracy of habitat evaluation for species with diverse habitat requirements, such as bobwhites. Small grid cells, while partially alleviating this problem, place additional demands on field time. Thus, for species with biological characteristics similar to bobwhites, the IMGRID system's usefulness is largely limited to intensive research projects.

We did find the IMGRID system very useful for identifying key elements and combinations of elements in bobwhite habitat, and for displaying these graphically. The system can enable the land use planner to pinpoint areas of poor habitat as well, and to delineate those habitat characteristics that are lacking.

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ESTIMATING BOBWHITE POPULATION SIZE BY DIRECT COUNTS AND THE LINCOLN INDEX

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Abstract: Thirteen paired estimates of bobwhite (Colinus virginianus) populations were obtained using the Lincoln Index and a Walk Census on two study areas in Florida and one in Tennessee. Population densities ranged from 1.0 to 7.6 birds/ha as estimated by the Lincoln Index. Unadjusted estimates obtained by the Walk Census averaged 51 percent of those obtained by the Lincoln Index. The correlation coefficient (r) for the 13 paired estimates was 0.96. The linear relationship between the Walk Census and Lincoln Index estimates was defined by $\hat{y} = 1.65x + 101.6$, where $\hat{y}$ = Lincoln Index estimate and x = Walk Census estimate. The Lincoln Index gave an unbiased estimate of the "true" population; either adjusting the Walk Census estimates by doubling the count or using the predictive equation generally produced acceptable estimates of the "true" population.

Assessing the effects of habitat manipulation and/or harvest regulations often requires measuring the animal population of interest. Capture-recapture methods and direct counts are two commonly used techniques for estimating the number of animals on defined areas (Davis and Winstead 1980). Both of these approaches have been used to evaluate bobwhite populations over a variety of habitat types. Managers and researchers continue to use variations of both these methods, though neither their accuracy nor precision have been clearly defined.

Capture-recapture estimates have used the Lincoln Index estimator in which bobwhites are captured in grain-baited live traps, banded, and released. A second sample is obtained either by shooting or trapping (Loveless 1958, Kellogg et al. 1972). Direct counts of bobwhites have usually been accomplished by workers systematically or randomly traversing an area and counting the coveys or individual birds flushed (Dimmick and Yoho 1972). Frequently, pointing bird dogs have been used to aid in locating the birds (Steen 1950, Robinson 1957, Loveless 1958, Roseberry and Klimstra 1972). Each method has its own set of advantages and disadvantages. Direct counts of flushed birds can be made comparatively quickly and require little equipment or expertise beyond simple map-reading and orientation skills. However, neither the proportion of the population counted nor the variability of this statistic over a range of habitat types and population densities has been defined. Population estimates based upon capture-recapture methods must necessarily comply with the standard assumptions regarding equal probability of capture, minimum recruitment-mortality, and retention of marks. In addition to these constraints, the technique often requires large investments of time and equipment to sample an area adequately. This approach, however, provides data which can be used to generate confidence intervals around the population estimate as well as a wealth of other population characteristics.

The primary objective of our study was to delineate relationships between the population estimate provided by the Lincoln Index and the direct count of flushed birds, which we term the Walk Census.

STUDY AREAS

Three areas were used for this study, a 234 ha tract on Ames Plantation, Fayette County, in southwest Tennessee and two tracts (204 and 212 ha) on Tall Timber Research Station, Leon County, in northwest Florida. The three areas were roughly similar in shape and size but encompassed two distinctly different habitat types.

Ames Plantation

The Ames Plantation study area was composed of cropland, idle lands, and forested areas. Forests were predominantly hardwoods in small tracts though some small stands of loblolly and shortleaf pines (*Pinus taeda* and *P. echinata*) were present also. Idle lands contained mature hardwoods scattered throughout extensive areas of broomsedge (*Andropogon virginicus*), creating the appearance of savanna. Forests contained moderately dense to dense growth of Japanese honeysuckle (*Lonicera japonica*) scattered abundantly throughout the understory. Croplands were composed of soybeans and cotton; these crops were usually harvested prior to the initiation of census work. Idle lands were burned in a checkerboard pattern on a two-year rotation, with about 50 percent being burned each year. Burning was accomplished after field studies were concluded for the year. Topography was flat to rolling; a major erosion ditch traversed the long mid-axis of the study area. Surface visibility ranged from very open to heavily obstructed by vegetation. An abundant winter food supply based on agriculture residues, dense protective cover, and high degree of interspersion of land uses provided excellent habitat quality for quail during the study period.

Tall Timbers Research Station

The Tall Timbers areas were composed principally of open, annually-burned, mature stands of loblolly and shortleaf pines with interspersed live oaks (*Quercus virginiana*). Understory was open, herbaceous plants dominating except for scattered experimental fire ecology plots, some of which were dense thickets of hardwoods and pine. Some low wet hammocks were occupied by live oak, beech (*Fagus grandifolia*, magnolia (*Magnolia grandiflora*), and other hardwoods. Several small fields of irregular shape were scattered throughout the areas; in some years they were planted to corn; in other years they were left fallow. Excellent visibility at surface level prevailed over almost all of both study areas. Topography was rolling. An abundance of natural foods enhanced by an annual prescribed fire program, some agricultural crop residues, and a generally mild winter climate provided an excellent environment for quail. A detailed description of the TTRS area was provided by Smith (1980).

METHODS

Lincoln Index

Quail were captured in live traps, banded with numbered aluminum leg bands, and released at the point of capture. Traps were placed at an average density of about one trap per two ha, but spacing was irregular as traps were set only in appropriate cover. Traps were baited with whole kernel or cracked corn. Trapping was continued until a very low percentage of captured birds was unbanded. Approximately 15 to 20 calendar days were required to capture sufficient numbers of quail for the estimate. Approximately two to three days following the end of trapping, systematic intensive shooting was inaugurated to collect a second sample of birds for computing the Lincoln Index. Shooting was continued until approximately one-half as many quail were shot on the area as had been banded in that year. The standard Lincoln Index then was applied to these data to obtain an estimate of the population.

The second sample (shooting) was obtained as quickly as possible following the end of trapping to reduce potential bias that could accrue from differential mortality and egress or ingress of banded vs unbanded birds. Some hunting and live-trapping were done on lands adjacent to the study areas to obtain an estimate of bias associated with egress of birds from the study area. Few marked birds were shot or trapped off the study areas, leading us to conclude that egress was not significant during the census period. Detailed information on movement of birds at Tall Timbers is given by Smith (1980).

On Ames Plantation, trapping and shooting were accomplished during November and December. On Tall Timbers this work was done during January and February.

Walk Census

Walk Censuses were conducted by teams of 5-10 persons traversing the entire study area by walking. Individuals maintained distances of approximately 20 m from persons on each side. One person served as leader and maintained direction using a handheld compass. The team worked as a unit, walking abreast at a moderate pace and maintaining appropriate spacing by visual and voice contact.

When quail were flushed, their number was counted and their location and direction of flight were noted on a detailed cover map. Questions concerning possible duplication of observed coveys, or disparate counts of the number of birds in a covey were answered immediately in the field at the point of action by consultation with team members and/or previously recorded data. When a covey was flushed but could not be counted, it was assigned a mean value determined at the conclusion of the count.

Walk Censuses were made during December on Ames Plantation and during February on Tall Timbers. A team of six persons required about 10-12 hours to complete the count on the Ames Plantation study area, and a team of 10 persons required about 8-10 hours for each of the Tall Timbers areas. Counts were made immediately following the end of a Lincoln Index trapping session and immediately prior to the initiation of shooting.

RESULTS

On the three study areas, 13 pairs of population estimates were achieved. In each case, the Lincoln Index estimate of population size was greater than its companion estimate made by the Walk Census (Table 1).

Lincoln Index Estimates

Lincoln Index estimates of population densities encountered on the study areas ranged from a low of 1.0 birds/ha on Tall Timbers South to 7.6

Table 1. Population estimation derived by Walk Censuses and the Lincoln Index on three study areas in Florida and Tennessee, 1972-1980.

		Walk Census		Lincoln Index			
Area	Year	No. Birds	Percent Flushed[a]	No. Birds	Standard Error	95% C.I.	Proportion of Population Marked[b]
Tall Timbers North							
	1972	867	56	1536	83	1370-1702	52
	1973	414	59	705	38	629-781	66
	1974	337	60	565	47	471-659	49
	1975	265	65	409	33	343-475	64
	1976	237	51	463	41	381-545	58
	1977	183	48	383	42	299-467	51
	1978	226	45	497	43	411-583	56
	1980	160	28	575	37	401-649	69
	$\overline{X}$		51.5				
Tall Timbers South							
	1978	138	64	216	31	154-278	50
	1979	239	48	496	44	408-584	55
	1980	214	40	535	60	415-655	48
	$\overline{X}$		50.7				
Ames Plantation							
	1972	548	52	1047	137	773-1321	27
	1973	395	47	848	90	668-1008	38
	$\overline{X}$		49.5				
Overall	$\overline{X}$		51.0				

[a]Percentage flushed calculated as proportion of Lincoln Index estimate of population counted during the Walk Census.
[b]Percentage of estimated population marked in capture phase of study.

birds/ha on Tall Timbers North, approximately embracing the range of densities that could be expected on moderate to excellent quail range in the Southeast (Table 2). However, the exceptionally high density of 7.6 birds/ha (3 birds/acre) observed one year on Tall Timbers North likely does not occur often nor for long periods of time on even the best southeastern quail range.

Table 2. Ranges in density of quail on each study area estimated by Walk Census and Lincoln Index.

Area	Birds/ha Walk Census	Birds/ha Lincoln Index
Tall Timbers North	0.8 - 4.3	1.9 - 7.6
Tall Timbers South	0.7 - 1.1	1.0 - 2.6
Ames Plantation	1.7 - 2.3	3.6 - 4.5

The proportion of birds marked during the capture phase of the estimate was quite high; on the Tall Timbers study areas it ranged from 48 to 69 percent (Table 1). Smaller proportions were marked on Ames Plantation, but even on this area the estimates of population size were judged acceptable.

Walk Census Estimates

The Walk Census produced consistently lower counts of quail than were known to be present on all study areas every year (Tables 1 and 2). Based upon this method of population assessment, densities ranged from 0.7 birds/ha on Tall Timbers South to 4.3 birds/ha (1.7 birds/acre) on Tall Timbers North.

Relationships between Lincoln Index and Walk Census Population Estimates

Assuming the Lincoln Index is an unbiased estimator for population numbers of bobwhites, we decided that it would be instructive from a management viewpoint to delineate the relationships between this labor-intensive method and the relatively simple Walk Census. Two approaches to evaluating this relationship appeared feasible, one using the percentage of birds estimated by the Lincoln Index flushed on its paired Walk Census, and another using more sophisticated correlation and regression analyses of the relationship between these two sets of data.

The proportion of birds flushed by the Walk Census averaged 51 percent for the 13 paired observations, ranging from 28 to 65 percent (Table 1). Eleven of the values, however, ranged from 45 to 65 percent; the two values outside this range occurred during the same year on the two Tall Timbers study areas, suggesting that circumstances prevailing during that census period may have been substantially different than in the other 11 censuses, but we can offer no explanation for what this difference may have been. Weather and personnel were similar to other years. Mean percentages of birds flushed were nearly identical for all three study areas, i.e., 49.5 percent for Ames Plantation, 50.7 percent for Tall Timbers South, and 51.5 percent for Tall Timbers North (Table 1). Thus, within the scope of habitat variability in our study, the proportion of birds flushed was not a function of habitat type. An examination of the relationship between population density (LI) and proportion of birds flushed also revealed no trend or statistical relationship (r = 0.0) between these statistics.

Assuming that 51 percent of the population is flushed and counted during a Walk Census, one can roughly estimate the "true" population by doubling the number counted. When we expanded our Walk Census estimate by this method, the adjusted population fell within the 95 percent confidence interval of the Lincoln Index estimate 8 of 13 times. Four estimates were slightly above the upper limit and one was markedly below the lower limit. Only three of the expanded estimates, however, deviated more than 25 percent above or below the LI estimate.

Regression and correlation analyses were very useful for estimating the degree of bias between the two estimators. The correlation coefficient for our 13 pairs of census figures was very high (r = 0.96). The predictive equation for these data was $\hat{y} = mx + b$, where

$\hat{y}$ = number of quail estimated by LI,
x = number of quail counted by WC,
m = 1.65, and
b = 101.6.

Since the estimated slope (m) of 1.65 is significantly different from one, the Walk Census is a biased estimate of the population.

The graphic representation of this equation is depicted by Figure 1. The relationship is clearly linear, and holds reasonably well through the range of densities measured in this study. Expanding the Walk Census count with this predictive equation produced very good estimates for dense and very dense populations, but markedly overestimated (52 percent) a very low population. Nine of 13 expanded estimates were within the C.I.

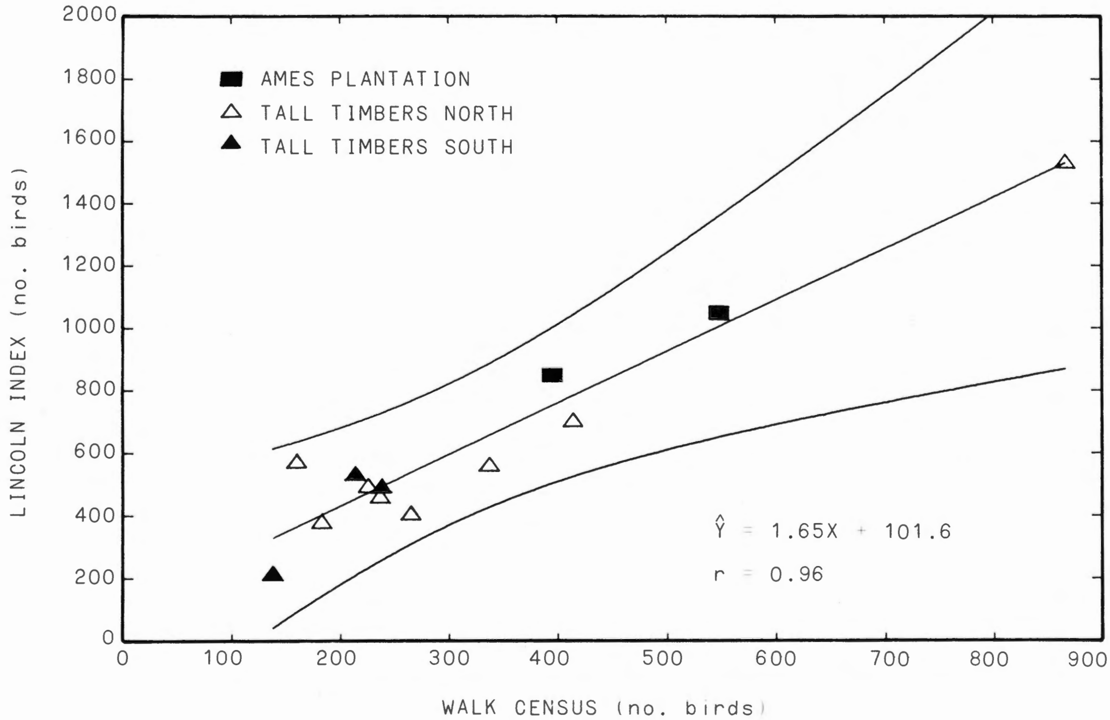

Fig. 1. Relationships between Walk Census estimate and Lincoln Index estimate on Tall Timbers and Ames Plantation study areas.

of the Lincoln Index estimate; three estimates deviated more than 25 percent from the LI estimate.

DISCUSSION AND CONCLUSIONS

We conclude that our methods for applying the Lincoln Index provided a close estimate of the bobwhite population on our study areas. Most germane to this conclusion is the stringency with which our study methods and the populations' behavior met the assumptions necessary for the Lincoln Index estimate to be accurate.

Our model was essentially a two-sample, short-term study of a closed population (see Pollock 1981). Our assumption that the populations were closed was greatly strengthened by Smith's (1980) detailed analysis of 10 years' banding data for the quail population on Tall Timbers Research Station. She described this population as extremely sedentary with movement so limited that it is not a major factor in population dynamics. She noted that trapping and shooting outside the boundaries of our study areas indicated little ingress or egress. The assumption of a closed population is further strengthened by the brief duration of the time over which the census was extended. Nichols et al. (1981) noted that selecting an appropriate time of year for sampling and allowing only a short period of time between samples will minimize violations of closure. On both Tall Timbers Research Station and Ames Plantation, the census was made when movement and mortality were low and natality was non-existent.

The assumption of equal catchability is not so clearly indicated, yet no strong biases were apparent in either the first or second sample on the basis of sex and age ratios. Pollock (1981) noted, however, that meeting the assumption of closure permits weakening the assumption of equal catchability. The problem of trap response bias for the second sample was negated by collecting that sample by shooting in a systematic fashion rather than live-trapping.

Band loss should be negligible for aluminum leg bands over a period of one to six weeks, and band reporting rate was 100 percent, since all hunting was conducted or monitored by researchers. The marked sample size was very high, averaging nearly 50 percent of the population, the lowest being 27 percent.

We agree with the evaluation of Nichols et al. (1981) that mark recapture studies can be useful in assessing other estimation methods and that in some situations mark recapture studies may be the most practical method for estimating population size. We conclude that our two-sample Lincoln Index provides the best estimate available for a closed population of bobwhites. By properly selecting boundaries for a study area, population size can readily be converted to population density.

This method of population estimation carries with it several advantages accrued from the handling of a large number of live and dead birds, specifically the opportunity to obtain sex and age ratios, movement data, population dynamics, health and condition data, etc. On the negative side of the ledger, the heavy cost in manpower, equipment, and money reduces the usefulness of this technique as a means for evaluating population trends in most management situations. Roughly 80-100 man-days were expended obtaining one estimate on one 200 ha area. Secondly, significant though not excessive mortality is imposed upon the population through trap-related deaths and shooting the second sample. The study method imposed roughly 25-30 percent mortality on the population.

The Walk Census appeared to be a reasonably precise, though biased, estimator of population numbers. It was simple and quick to execute. It correlated reasonably well with the Lincoln Index estimate over a range of conditions and a period of several years; thus we are confident that it can be highly useful as an indicator of population trends. For our study areas, it was a good indicator of population size when expanded by appropriate computations. We would be uncomfortable expanding estimates for Walk Censuses conducted in habitats greatly dissimilar from ours, e.g. very open habitats of prairie regions, but suggest that such adjustments may be acceptable for much of the midwest, midsouth, and deep south quail range.

Perhaps the greatest advantage of the Walk Census is the ease and speed with which it can be accomplished. A single estimate for a 200 ha area can be obtained with an expenditure of 8-10 man days, roughly 10 percent of the time required for the Lincoln Index. Using the appropriate number of researchers, this can be accomplished in one to two calendar days, in contrast to the 30+ calendar days required for trapping and shooting for the Lincoln Index. The Walk Census has an added advantage of imposing no mortality on the population. When researchers conduct a Walk Census, they should adhere to the following precautions:

1. Select sampling areas that are reasonably regular in shape, with boundaries as close to perpendicular as possible.

2. Use line-of-sight compasses to control direction of traverse, and adhere carefully to compass direction, walking through all cover types and densities with equal care and consistency of attention.

3. Avoid using hunting dogs. It adds another variable.

4. Carefully maintain spacing of approximately 20 m between workers. Using fluorescent orange vests and hats greatly enhances this aspect, particularly where visibility is restricted.

5. Maintain accurate records on location of coveys flushed and direction of flight. Resolve discrepancies between observers in counts immediately.

6. Walk 100 percent of the area to be censused. Our attempts at projecting data from 20 percent strip censuses failed utterly.

Following these guidelines, personnel with little training can use the Walk Census effectively, provided the team leader maintains control of personnel. The manager or biologist may enlist the aid of interested non-professionals to determine and demonstrate the relationship between habitat conditions on a given area and the density of its bobwhite population, reducing costs further with little or no sacrifice in quality of the estimate.

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EVALUATION OF BOBWHITE QUAIL SURVEYS IN KANSAS

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Abstract: Statistical analysis of selected Kansas bobwhite (*Colinus virginianus*) population and harvest surveys is presented. Survey techniques evaluated include roadside counts by rural mail carriers (RMCS), April roadside counts, whistling cock counts, random summer brood counts (RSBC), interviews of hunters contacted during the hunting season, wing collection envelopes distributed to hunters, and a mail questionnaire harvest survey of hunters. Significant differences ($P < 0.05$) between years and between survey regions existed for the April RMCS, April roadside count (coveys/observer), June whistle count, RSBC (young/adult and young/adult hen), and July RMCS. Correlation tests indicated significant ($P < 0.1$ to 0.001) correlation coefficient (r) values between many of the population surveys, and between many of the population surveys and harvest parameters. The October RMCS is the best single predictor of harvest parameters. When the October RMCS (quail/100 miles) is used in association with adults/observer (RSBC) and total quail/observer (RSBC), higher R^2 values are obtained as determined by stepwise multiple regression with harvest parameters.

Numerous bobwhite population monitoring techniques have been used in states containing significant numbers of this game bird. The most common techniques include the use of flush count census (Bennett and Hendrickson 1938), standardized roadside counts (Stiles and Hendrickson 1946, Fisher et al. 1947), whistling cock counts (Bennett 1951), random observations (Stanford 1972), and rural mail carrier counts (Dey 1971). In order to be of use for detecting population change and/or predicting harvest rates, any technique used must 1) be of sufficient sensitivity to detect significant annual change in bobwhite numbers; 2) cover a large enough geographic area in order to represent statewide and/or regional population levels; 3) not require such extensive manpower commitments that it would be rendered financially unfeasible; and 4) display a significant relationship to independent harvest estimates.

This paper discusses selected techniques used to monitor Kansas bobwhite populations and harvest, and the statistical relationships that exist between the various methods. The inventories considered here fall into 5 general categories: 1) those which measure pre-breeding bird densities; 2) those taken during the breeding and brood rearing period; 3) those which measure the pre-hunting season population; 4) those which measure bobwhite hunter performance; and 5) those which measure changes in age and sex ratios through collection of biological materials.

For survey purposes, Kansas is divided into 6 physiographic regions: West, Northcentral, Southcentral, Flint Hills, Northeast, and Southeast. The major bobwhite range is in the Flint Hills, Northeast, and Southeast regions with slightly lower densities in the Northcentral and Southcentral regions. The West Region has generally scattered low density bobwhite populations.

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METHODS

Pre-breeding Inventories

April rural mail carriers survey (RMCS)

Starting in 1963, rural mail carriers recorded all quail seen during their normal deliveries for a four-day period during the last full calendar week of April. In 1970, the count period was extended to a five-day period. On a postcard supplied by the Fish and Game Commission, each carrier records the post office from which his route originates, counties traveled, and the number of miles traveled each day. Carriers are asked not to record observations on days of heavy fog or rain. An average of 550 carriers participate in the count and drive approximately 250,000 miles during the survey. A population index (quail/100 miles) is derived from data reported.

April roadside counts

Initiated in 1966, the April roadside count was designed to collect survey data from a 70 mile route for four days during the second full calendar week of April. The survey was intended to be similar to the rural mail carriers survey so that comparisons between the two could be made. However, after the first year it was evident that covey breakup and breeding activity affected the birds observability and thus survey results. It was decided to discontinue the route system and run the survey for the entire month of April and record random quail observations made while carrying out other work assignments. Fish and Game law enforcement officers and biologists in the eastern two-thirds of the state were asked to record, by weekly intervals, quail seen as coveys if more than three birds were seen, and the number of birds in each covey. The number of trios, pairs, and singles were also recorded. Indices used in this analysis were coveys seen/observer and total quail/observer. This survey was conducted for three years, 1967-1969.

Breeding and Brood Inventories

July RMCS

The July RMCS was initiated in 1962 and is conducted similarly to the April RMCS with the exception that carriers are asked to differentiate between young and adult quail seen. The indices derived from this survey include adults seen/100 miles, young seen/100 miles, total quail seen/100 miles, and young/adult. This survey has been conducted from 1962 to present.

Whistling cock counts

From 1963-1965, whistling cock counts were conducted during the second week of July. Thirty routes, each 14 miles long with 15 stops, were run in selected counties throughout the state.

In 1966, the July whistle count survey was replaced by two survey periods, June 1-10 and August 10-20. Twenty-five routes were run in the eastern two-thirds of Kansas. The routes were nine miles long with 10 listening stops (one per mile) for each route. The counts, conducted by Fish and Game law enforcement officers and biologists, started at sunrise on mornings with winds < 12 mph and no threat of rain. Listening stops lasted three minutes, and the number of different males heard calling "bobwhite" was recorded. Observers were instructed not to whistle in order to stimulate calling.

The index derived from the whistling cock counts was males heard calling/stop. The June and August counts were conducted from 1966 to 1971.

Random summer brood counts (RSBC)

From 1963 to present, random brood counts have been conducted by Fish and Game personnel. In 1963 and 1964, the counts were made during a five-week period; July 15-August 18 and July 20-August 23, respectively. In 1965, the count was changed to cover a six-week period beginning in mid-July; in 1971 only five weeks of data were collected due to an error in the instructions.

Personnel were instructed to record all sightings of adult (separating cocks and hens) and young quail while conducting routine work assignments. With the aid of aging photographs, young were aged to the nearest week. Other information recorded was date, time of day to nearest hour, and county or Wildlife Management Area where the observations were made. Data sheets were sent in on a weekly basis.

Indices calculated from the brood count data are broods seen/observer, young seen/observer, males seen/observer, females seen/observer adults seen/observer, total quail seen/observer, young/brood, young/adult female, young/adult, and adult males/100 adult females. Hatch date information is not presented in this report.

Pre-Hunting Season Survey

October RMCS

The October RMCS survey has been conducted annually since 1966. Rural mail carriers record the number of bobwhites observed during a five-day period. The index derived from this survey is total quail observed/100 miles of route.

Hunter Surveys

Random bag-checks

The quail hunter bag-check was initiated in 1961 and continued through 1972. Fish and Game law enforcement officers and biologists located in the eastern two-thirds of Kansas were instructed to contact quail hunters in the field during the season in order to gather hunter performance and quail harvest data.

Information recorded in 1961 and 1962 for each hunter checked included county in which check was made, date, total number of birds bagged (by age), number of cripples lost, total number of hours hunted (separated by A.M. and P.M.), whether or not a dog was used, and whether or not the hunter had completed his hunt for that day. From 1963-1972, the following information was collected for each party contacted: county in which check was made, date, number of hunters in party, total number of birds bagged (by sex), number of cripples lost, number of coveys flushed, total number of hours hunted (separated by A.M. and P.M.), whether or not a dog was used, and whether or not the party had completed its hunt for that day.

Indices used for this analysis were coveys flushed/party hour, birds bagged/gun hour, bag/hunter, gun hours/hunter, cripples lost/100 birds bagged, and males/100 females.

Statewide harvest mail survey

The statewide harvest mail survey has been conducted from 1957 to present. A harvest estimate is obtained by sending mail questionnaires to a five percent sample of the previous year's hunting license buyers. These persons are contacted prior to the hunting seasons, and are sent forms for maintaining a record of their hunting activity (birds bagged on each hunt). At the close of the hunting seasons, they are contacted by mail and asked to report their total hunting activity including county hunted most, number of days spent quail hunting and total birds bagged. Of the license buyers contacted, generally over 40 percent return useable information representing about two percent of the current year's hunting license buyers. Indices and harvest figures used for this analysis include average bag/day per hunter, season bag/hunter, and estimated statewide harvest.

Wing collections

In an attempt to obtain age data for quail harvested, approximately 3,000 pre-addressed postage-paid wing envelopes were distributed to quail hunters by Fish and Game law enforcement officers during the quail season from 1962-1970. Instructions for removing one wing from each bird bagged during a hunt and for mailing the wings were printed on the envelope. The hunter was also asked to record on the envelope the county where birds were taken, date taken, and name and address of hunter. In addition to wing envelopes sent in by hunters, law enforcement officers and biologists were provided envelopes for collecting wings from those birds checked during opening weekend hunter bag-check interviews. These wings were kept separate according to sex. Wings were aged by the small game staff. Stage of primary feather molt for both young and adult wings were recorded to the nearest one-half feather increment and later classified by weeks of age.

Indices calculated and used in this analysis include young/adult, young/adult female, males/100 females, adult males/100 adult females, young males/100 young females, and percentage young.

Analysis

In 1973, one-way and two-way analysis of variance tests were performed on statewide and regional data at the Kansas State University (KSU) Statistical laboratory. More recently, simple correlation, regression, and stepwise regression analysis using the Statistical Analysis System (SAS) computer package were performed at the KSU Statistical Laboratory.

RESULTS

Pertinent data from the April roadside counts; June, July, and August whistle counts; April, July, and October RMCS; RSBC; mail harvest survey; random bag check, and wing collection are summarized in Tables 1-6.

In a previous analysis of Kansas bobwhite surveys (Sexson 1973), two-way analysis of variance tests were performed on all population surveys. Significant differences existed ($P < 0.05$) between survey years and survey regions. However, August whistle count indices were not significantly different among years, the RSBC index young/brood (years 1963-1972 only) did not vary significantly ($P > 0.05$) among years, and the wing collection indices young/adult and percentage young did not vary significantly among regions ($P > 0.05$).

Table 1. Bobwhite population indices from the April roadside count and June, July and August whistle counts in Kansas, 1963-71.

Year	Quail/Observer April Road Ct.	Coveys/Observer April Road Ct.	Males/Stop June W.C.	Males/Stop July W.C.	Males/Stop Aug. W.C.
1963	---	---	---	2.8	---
1964	---	---	---	5.1	---
1965	---	---	---	4.0	---
1966	---	---	4.9	---	2.1
1967	85	5.9	5.3	---	3.0
1968	65	5.0	4.5	---	2.2
1969	55	3.8	4.6	---	2.9
1970	---	---	4.4	---	1.5
1971	---	---	3.3	---	2.4
$\overline{X}$	68.3	4.90	4.50	3.97	2.35

Table 2. Bobwhite population indices from rural mail carrier counts in Kansas, 1962-80.

Year	Quail/100mi. April	Quail/100mi. July	Young/100mi. July	Adults/100mi. July	Young/Adult July	Quail/100mi. October
1962	----	4.80	1.73	2.78	0.62	----
1963	2.81	6.49	2.63	3.52	0.75	----
1964	2.28	5.80	1.75	3.88	0.45	----
1965	1.93	6.29	1.88	4.20	0.45	----
1966	3.05	7.35	2.71	4.50	0.60	6.52
1967	3.14	7.70	1.50	5.89	0.25	4.52
1968	1.92	7.62	2.44	4.87	0.50	5.93
1969	1.46	8.68	2.46	6.02	0.41	4.28
1970	1.54	5.54	1.65	3.73	0.44	4.85
1971	1.57	4.72	1.47	3.07	0.48	3.47
1972	1.56	6.95	2.61	4.08	0.64	3.34
1973	1.41	5.52	1.65	3.60	0.46	3.02
1974	1.38	3.54	1.29	2.18	0.59	1.95
1975	0.95	2.76	0.74	1.90	0.39	2.51
1976	1.05	2.92	0.90	1.89	0.48	2.48
1977	1.19	3.73	1.29	2.24	0.57	2.02
1978	0.98	4.18	1.17	2.83	0.41	3.19
1979	0.61	1.89	0.52	1.19	0.44	1.34
1980	0.50	1.70	0.62	0.99	0.63	1.67
$\bar{X}$	1.63	5.17	1.63	3.34	0.50	3.40

Table 3. Bobwhite population indices from random brood counts in Kansas, 1963-80.

Year	Broods/ Observer	Total Quail/ Observer	Young/ Observer	Adults/ Observer	Males/ Observer	Females/ Observer	Young/ Brood	Young/ Female	Young/ Adult	Males/100 Females
1963	12.78	210.4	158.5	51.95	30.32	21.63	12.41	7.33	3.05	140.2
1964	13.09	226.4	158.4	67.98	37.85	30.13	12.10	5.26	2.33	125.6
1965	12.98	209.9	141.9	67.98	39.67	28.30	10.94	5.01	2.09	140.2
1966	16.24	248.6	184.6	63.94	35.06	28.89	11.37	6.39	2.89	121.3
1967	6.37	118.6	62.5	56.07	34.17	21.90	9.82	2.85	1.11	156.0
1968	7.70	124.3	83.4	40.83	23.89	16.94	10.84	4.93	2.04	141.0
1969	11.25	181.8	123.3	58.42	33.21	25.22	10.97	4.89	2.11	131.7
1970	8.40	125.7	91.7	33.97	18.93	15.04	10.91	6.10	2.70	125.8
1971	3.84	62.8	40.5	22.34	13.24	9.11	10.53	4.44	1.81	145.4
1972	12.16	171.3	130.2	41.16	23.23	17.93	10.70	7.26	3.16	129.6
1973	9.27	133.8	90.2	43.67	26.98	16.69	9.72	5.40	2.06	161.6
1974	4.76	69.4	49.3	20.11	11.49	8.61	10.36	5.73	2.45	133.5
1975	5.26	79.4	56.6	22.87	13.36	9.52	10.76	5.94	2.47	140.3
1976	5.85	84.7	60.8	23.91	13.64	10.28	10.39	5.92	2.54	132.7
1977	5.23	82.7	54.4	28.34	16.83	11.50	10.40	4.73	1.92	146.4
1978	4.80	78.4	52.7	25.70	15.35	10.35	10.99	5.10	2.05	148.3
1979	1.92	27.6	15.2	12.34	7.67	4.67	7.93	3.26	1.23	146.3
1980	3.74	52.6	40.3	12.29	6.56	5.74	10.76	7.02	3.28	114.3
$\bar{X}$	8.09	127.1	88.5	38.55	22.30	16.25	10.66	5.41	2.30	138.8

Table 4. Bobwhite population indices from wing collections in Kansas, 1963-70.

Year	Young/ Adult	Young/ Ad. Female	% Young	Males/100 Females	Adult Males/ 100 Ad. Females	Young Males/ 100 Yng. Females
1963	5.48	11.92	84.57	95.50	117.40	91.90
1964	3.20	6.67	76.19	105.00	108.30	104.00
1965	4.98	10.39	83.27	105.70	108.60	105.10
1966	4.24	9.08	80.92	107.40	114.00	105.80
1967	4.15	8.95	80.59	101.70	115.50	98.60
1968	5.65	12.67	84.97	96.50	124.10	92.40
1969	4.48	9.33	81.75	101.20	108.20	99.60
1970	4.64	8.44	82.28	86.50	81.70	87.50
$\overline{X}$	4.60	9.68	81.80	99.90	109.70	98.10

Table 5. Bobwhite harvest data from random hunter bag checks in Kansas, 1961-1972.

Year	Coveys Flushed/Hour	Bag/ Gun Hour	Bag/ Hunter Day	Gun Hours/ Hunter	Cripples/100 Birds Bagged	Males/100 Fem. Bagged
1961	----	0.72	2.53	3.53	11.46	-----
1962	----	0.93	3.46	3.73	8.16	-----
1963	0.82	1.11	2.92	2.64	13.90	103.1
1964	0.77	0.75	2.53	3.36	11.78	104.3
1965	0.80	0.80	2.79	3.50	10.91	100.7
1966	0.93	0.96	2.83	2.95	12.03	105.5
1967	0.68	0.74	2.23	3.03	11.93	103.8
1968	0.82	0.85	2.70	3.19	11.68	101.6
1969	0.87	0.86	2.61	3.02	12.44	101.8
1970	0.73	0.69	2.16	3.15	13.66	104.4
1971	0.67	0.61	1.98	3.26	13.75	107.3
1972	0.79	0.64	1.80	2.81	-----	-----
$\overline{X}$	0.79	0.80	2.54	3.18	11.97	103.6

Figure 1 presents results of correlation testing of selected indices within random bag checks, wing collection, roadside counts, whistle counts, RMCS, and RSBC surveys.

There was no significant relationship ($P > 0.10$) between the number of males/stop from the June whistle count and males/stop from the August whistle count, but there were significant relationships between April RMCS, July RMCS, and October RMCS. Schwartz (1974b) found a significant ($P < 0.05$) relationship between quail heard in July and quail observed in August.

Intersurvey Testing

Significant relationships existed between the April RMCS and various indices from the RSBC (Table 7). The number of adults/100 miles and total quail/100 miles from the July and October RMCS were significantly ($P < 0.10$ to 0 .01) related to most RSBC indices. The young/adult index from the July RMCS was significantly ($P < 0.01$) correlated with the young/adult index from the RSBC. Highest $\underline{r}$ values existed between the indices young/100 miles (July RMCS) and broods/observer (RSBC), ($r = 0.837$, $P < 0.01$) and between quail/100 miles (July RMCS) and males/observer (RSBC), ($r = 0.835$, $P < 0.01$).

Males/stop from the June whistle count was significantly correlated with males/observer (RSBC), ($r = 0.876$, $P < 0.05$), and adults/observer (RSBC), ($r = 0.847$, $P < 0.05$) but weakly correlated ($P < 0.10$) with adults/100 miles (July RMCS), ($r = 0.779$); total quail/100 miles (July RMCS), $r = 0.748$); and females/observer (RSBC), ($r = 0.789$).

Quail/observer from the April roadside count was significantly related to total quail/100 miles (April RMCS), ($r = 0.998$, $P < 0.05$). However, there were only three years' data available for analysis. Males/stop (July whistle

Table 6. Bobwhite harvest data from statewide harvest mail survey in Kansas, 1961-80.

Year	Avg. Bag/ Day	Season Bag/ Hunter	Total Harvest
1961	2.96	10.80	1,076,000
1962	3.48	14.30	1,520,000
1963	4.06	17.66	2,126,000
1964	3.59	19.67	2,573,000
1965	3.83	19.69	2,631,000
1966	3.87	25.07	3,931,000
1967	3.26	15.94	2,426,000
1968	3.50	20.09	3,050,000
1969	3.59	20.68	3,301,000
1970	3.04	17.06	2,733,000
1971	2.56	14.71	2,284,000
1972	2.73	16.55	2,618,000
1973	2.70	15.11	2,307,000
1974	2.06	11.66	1,772,000
1975	2.27	12.90	1,912,000
1976	2.43	13.91	2,068,000
1977	2.72	14.86	2,263,000
1978	2.70	15.96	2,569,000
1979	1.90	9.50	1,193,000
1980	1.87	9.35	1,186,000
$\overline{X}$	2.96	15.77	2,276,950

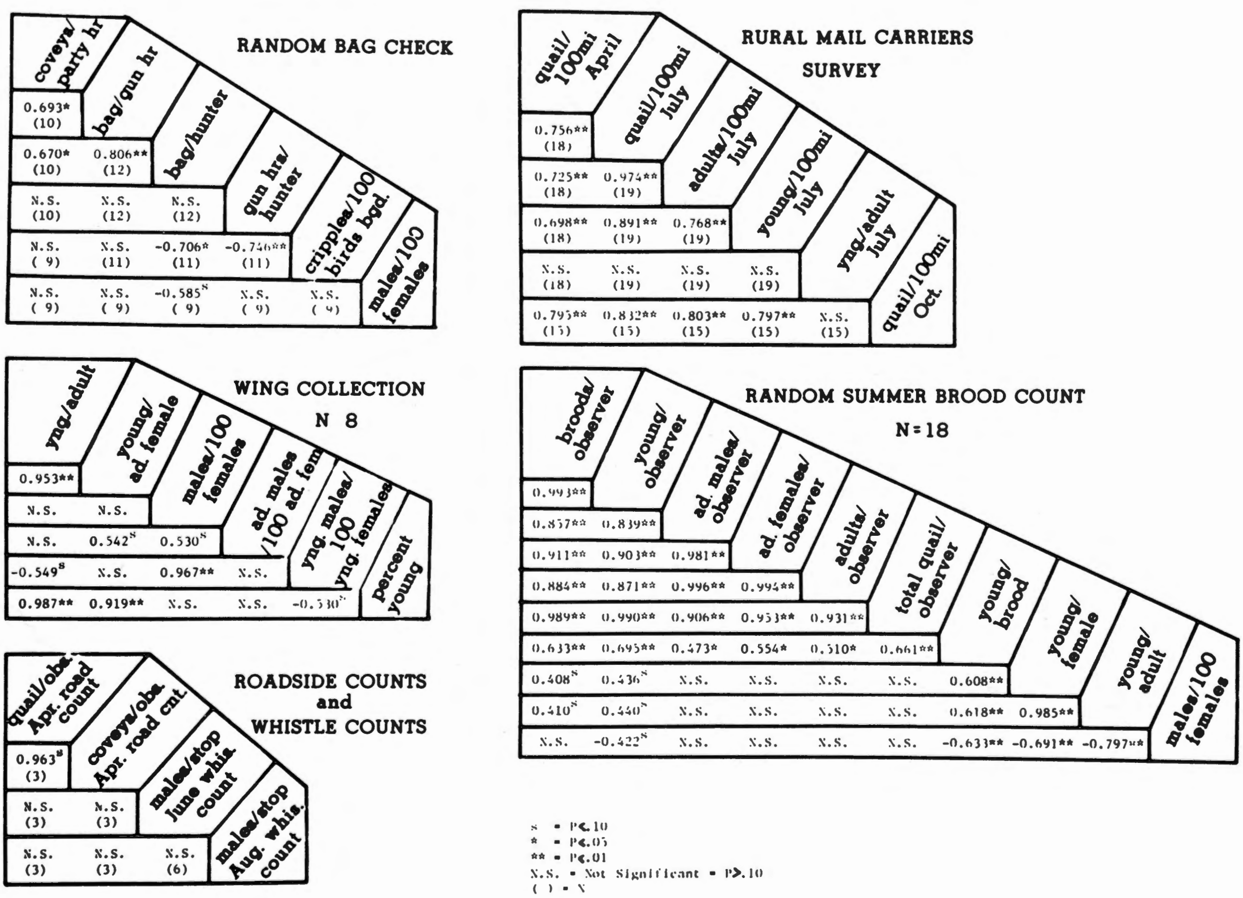

Fig. 1. Correlation coefficients (r) between indices of selected population and harvest surveys in Kansas, 1961-1980.

Table 7. Correlation coefficients resulting from tests between bobwhite population indices obtained from rural mail carriers survey and random summer brood count in Kansas, 1963-1980.

	Q/100mi April (18)	Ad/100mi July (18)	Yng/100mi July (18)	Total Q/100mi July (18)	Yng/Ad July (18)	Q/100mi October (15)
Broods/Obs	0.683**	0.635**	0.837**	0.732**	N.S.	0.731**
Yng/Obs	0.691**	0.560**	0.826**	0.702**	N.S.	0.735**
Males/Obs	0.798**	0.826**	0.726**	0.835**	N.S.	0.775**
Females/Obs	0.782**	0.791**	0.754**	0.816**	N.S.	0.819**
Adults/Obs	0.794**	0.815**	0.742**	0.830**	N.S.	0.799**
Total Quail/ Observer	0.739**	0.675**	0.825**	0.757**	N.S.	0.780**
Yng./Brood	0.460^s	N.S.	0.556*	0.406^s	N.S.	0.513^s
Yng/Ad Female	N.S.	N.S.	N.S.	N.S.	0.775**	N.S.
Yng/Adult	N.S.	N.S.	N.S.	N.S.	0.733**	N.S.
Adult Males/100 Adult Females	N.S.	N.S.	N.S.	N.S.	-0.438^s	N.S.

(N) = Number of years compared
^{s} = $P < 0.10$
* = $P < 0.05$
** = $P < 0.01$
N.S. = $P > 0.10$

count) was weakly related to broods/observer (RSBC), ($r = 0.989$, $P < 0.10$), but again, there were only three years' data for analysis. Males/stop from the August whistle count showed a weak negative relationship to the number of young/adult female (RSBC), ($r = -0.783$, $P < 0.10$, $N = 6$).

The index average bag/day (mail survey) was highly correlated with bag/gun hour ($r = 0.872$, $P < 0.01$) and bag/hunter ($r = 0.748$, $P < 0.01$) (Table 8). The best relationship existed between the season/bag hunter (mail survey) and coveys flushed/party hour (bag check), ($r = 0.894$, ($P < 0.01$).

Of those whistle count indices with at least six years of data for analysis, only males/stop from the June count showed a significant relationship with average bag/day from the mail survey ($r = 0.734$, $P < 0.10$), (Table 9). No significant relationships existed between August whistle count data and mail harvest indices.

In analysis between whistle counts and random bag checks, where at least six years of data were available for testing, only males/stop from the June whistle count and gun hours/hunter (random bag check) showed significant relationship ($R = -0.810$, $P = 0.05$). No August whistle count data were significantly correlated with random bag checks.

Table 8. Correlation coefficients resulting from tests between hunter performance data obtained from random bag checks and statewide harvest mail survey in Kansas, 1961-1972.

Bag Check	Mail Harvest Survey: Avg Bag/ Day	Season Bag/ Hunter	Total Harvest
Coveys Flushed/ Party Hour	0.682* (10)	0.894** (10)	0.760* (10)
Bag/Gun Hour	0.872** (12)	N.S. (12)	N.S. (12)
Bag/Hunter	0.748** (12)	N.S. (12)	N.S. (12)

(N)=Number of years compared
^{s} = $P < 0.10$
* = $P < 0.05$
** = $P < 0.01$
N.S. = $P > 0.10$

Studies have shown the use of whistle counts as an index to quail populations (Bennett 1951, Brown et al. 1978). Ellis et al. (1972) concluded that carefully standardized call counts would provide reliable indices to quail relative abundance in Illinois; however, Preno and Labisky (1971) also working in Illinois, found no significant relationship between spring abundance as determined from whistle counts and fall harvest statistics. In an analysis of Iowa quail survey data, Schwartz (1974a, 1974b) found significant relationships between July whistle counts and the mail survey indices of total harvest ($P < 0.05$) and average bag/day ($P < 0.10$).

Correlations between RMCS indices and bag check data showed high r values between quail/100 miles (October RMCS) and bag/hunter ($r = 0.866$, $P < 0.05$); young/100 miles (July RMCS) and coveys flushed/party hour ($r = 0.855$, $P < 0.01$); and quail/100 miles (October RMCS) and bag/gun hour ($r = 0.832$, $P < 0.05$) (Table 10).

Quail/100 miles (October RMCS) was shown to be the best predictor of the subsequent harvest as measured by the statewide harvest mail survey (Table 11). The best relationship exists between quail/100 miles (October RMCS) and average bag/day ($r = 0.924$, $P < 0.01$), (Figure 2). Significant relationships existed between each harvest parameter and all of the RMCS indices except young/adult in July. Ammann and Ryel (1963) concluded that rural mail carrier surveys were a good index to ruffed grouse populations in Michigan. In Nebraska, they have been in use since 1945 (Dey 1971).

The index coveys flushed/party hour (random bag-check) was significantly correlated ($P < 0.01$) with broods/observer ($r = 0.815$), young/observer ($r = 0.792$), and total

Table 9. Correlation coefficients resulting from tests using indices obtained from random April observations and whistle counts with harvest parameters from the statewide harvest mail survey in Kansas, 1963-1971.

Harvest Parameters	Population Surveys: Q/Obs April (3)	Covey/Obs April (3)	Males/Stop June (6)	Males/Stop July (3)	Males/Stop August (6)
Avg Bag/ Day	-0.998*	N.S.	0.734^{s}	-0.999*	N.S.
Season Bag	N.S.	N.S.	N.S.	N.S.	N.S.
Total Harvest	-0.999*	N.S.	N.S.	N.S.	N.S.

(N)=Number of years compared
^{s} = $P < 0.10$
* = $P < 0.05$
** = $P < 0.01$
N.S. = $P > 0.10$

Table 10. Correlation coefficients resulting from testing between bobwhite population indices obtained from rural mail carrier surveys and hunter performance data from the random bag check in Kansas, 1962-1972.

Harvest Parameters	Rural Mail Carriers Survey: Q/100mi April	Ad/100mi July	Yng/100mi July	Total Q/100mi July	Yng/Ad July	Q/100mi October
Coveys flushed/ Party Hour	N.S. (10)	N.S. (10)	0.855** (10)	0.565^{s} (10)	N.S. (10)	N.S. (7)
Bag/Gun Hour	0.556^{s} (10)	N.S. (11)	0.546^{s} (11)	N.S. (11)	0.531^{s} (11)	0.832^{s} (7)
Bag/Hunter	N.S. (10)	N.S. (11)	N.S. (11)	N.S. (11)	N.S. (11)	0.866* (7)

(N) = Number of years compared
^{s} = $P < 0.10$
* = $P < 0.05$
** = $P < 0.01$
N.S. = $P > 0.10$

Table 11. Correlation coefficients resulting from testing between bobwhite population indices obtained from rural mail carrier surveys and hunter performance data from the statewide harvest mail survey in Kansas, 1962-1980.

Harvest Parameters	Rural Mail Carriers Survey					
	Q/100mi April (18)	Ad/100mi July (19)	Yng/100mi July (19)	Total Q/100mi July (19)	Yng/Ad July (19)	Q/100mi October (15)
Avg Bag	0.812**	0.751**	0.813**	0.816**	N.S.	0.924**
Season	0.715**	0.791**	0.831**	0.841**	N.S.	0.912**
Total Harvest	0.604**	0.783**	0.743**	0.800**	N.S.	0.896**

(N) = Number of years compared
** = P < 0.01
N.S. = P > 0.10

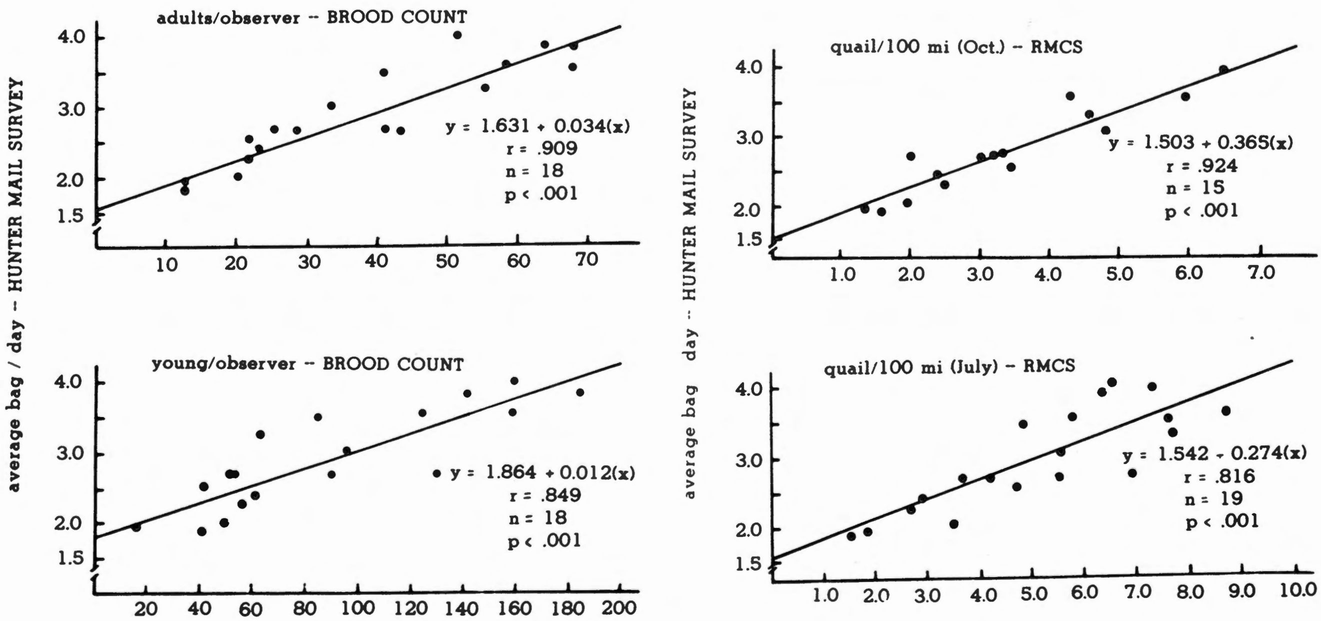

Fig. 2. Relationships of selected random summer brood count and rural mail carrier survey indices to the mail harvest survey index average bag/day in Kansas, 1962-1980.

quail/observer (r = 0.771) from the RSBC, (Table 12). Bag/gun hour was significantly correlated with the young/brood (r = 0.637, P < 0.05) and bag/hunter was significantly (P < 0.05) correlated with males/observer (r = 0.645), females/observer (r = 0.641), adults/observer (r = 0.649), and total quail/observer (r = 0.641).

All of the brood count indices except young/adult female and young/adult were correlated with the statewide harvest mail survey indices (Table 13). The best predicator of 1) average bag/day was adults/observer (r = 0.909, P < 0.01), (Figure 3); 2) season bag/hunter was females/observer (r = 0.875, P < 0.01); and 3) statewide harvest was females/observer (r = 0.740, P < 0.01); however, broods/observer (r = 0.724, P < 0.01) and total quail/observer (r = 0.721, P < 0.01), (Figure 2) also provided high r values. The broods/observer index, which is similar to the production index (PI) described by Stanford (1972), was significantly (P < 0.01) correlated with the statewide harvest mail survey parameters (Figure 2).

There were no significant relationships (P > 0.10) between the wing collection indices young/adult, young/adult female, or percentage young and April roadside counts; June, July, or August whistle counts; RMCS; and mail survey harvest indices.

Multiple Regression Analysis

Stepwise maximum R^2 improvement multiple regression analysis was performed between the statewide mail survey harvest indices (average bag/day, season bag/hunter, and total harvest)

Table 12. Correlation coefficients resulting from testing between bobwhite population indices obtained from the random summer brood count and hunter performance data from random bag checks in Kansas, 1963-1972.

Harvest Parameters	Random Summer Brood Count						
	Broods/ Obs (10)	Young/ Obs (10)	Males/ Obs (10)	Females/ Obs (10)	Adults/ Obs (10)	Total Q/ Obs (10)	Young/ Brood (10)
Coveys Flushed/ Party Hour	0.815**	0.792**	N.S.	0.608^s	N.S.	0.771**	N.S.
Bag/Gun Hour	0.564^s	0.617^s	N.S.	N.S.	N.S.	0.617^s	0.637*
Bag/Hunter	0.552^s	0.593^s	0.645*	0.641*	0.649*	0.641*	0.581^s

(N) = Number of years compared
^{s}= P < 0.10
* = P < 0.05
** = P < 0.01
N.S. = P > 0.10

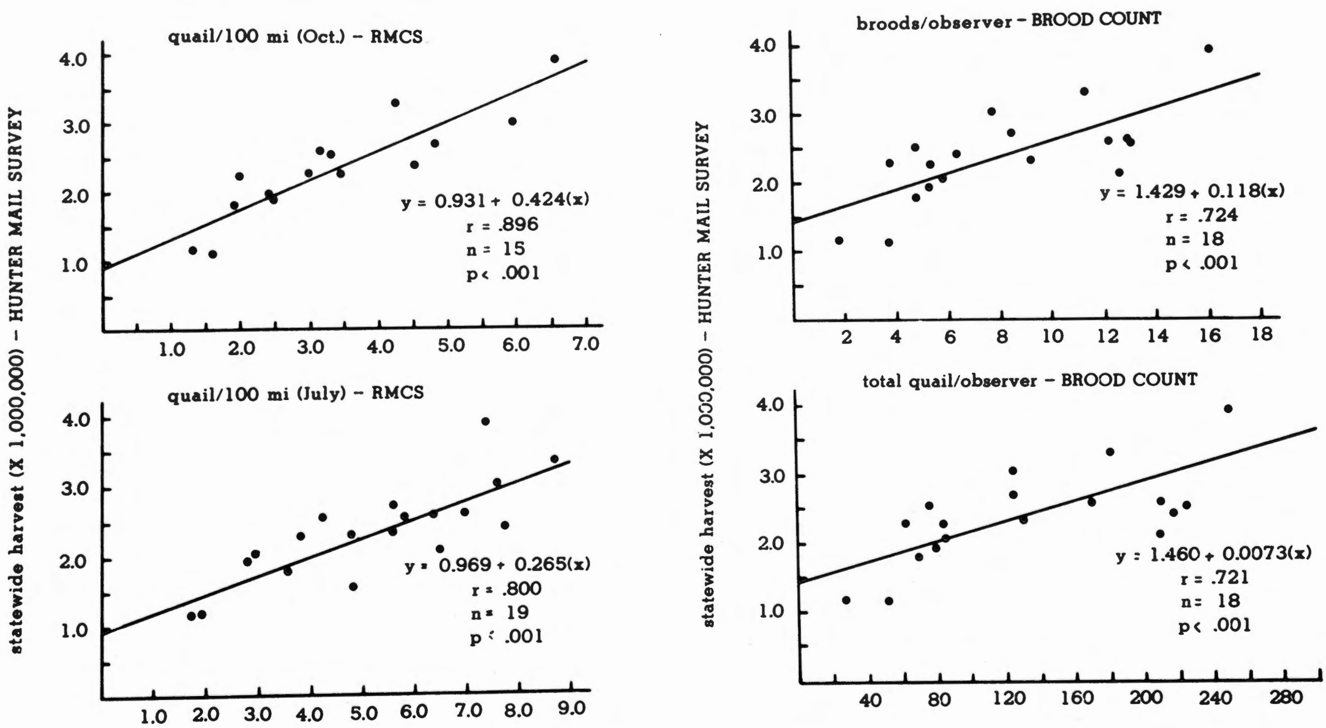

Fig. 3. Relationships of selected random summer brood count and rural mail carrier survey indices to the mail harvest survey index statewide (total) harvest in Kansas, 1962-1980.

and RMCS indices; between the harvest indices and RSBC indices, and between the harvest indices and a group composed of selected indices from both population surveys. In almost every instance the best two variable model was accepted. Although models with three or more variables provided slightly higher R^2 values, the improvement was generally not deemed significant enough to warrant further complication of the predicting formula. In all instances P < 0.001.

When RMCS indices alone were used, the best model for predicting average bag/day included quail/100 miles (July) and quail/100 miles (October), (R^2 = 0.916, F = 65.66). The best model for predicting season bag/hunter included young/100 miles (July) and quail/100 miles (October), (R^2 = 0.894, F = 50.84). The best model for predicting total quail harvest included young/100 miles (July) and quail/100 miles (October), (R^2 = 0.879, F = 43.42).

When RSBC indices alone were tested, the best two variable predictor for average bag/day included males/observer and young/brood (R^2 = 0.873, F = 51.44). The best model for predicting season bag/hunter included males/observer and females/observer (R^2 = 0.786, F = 24.32). The best model for predicting total quail harvest included females/observer and adults/observer (R^2 = 0.570, F = 9.96).

Improved R^2 values were achieved when both RMCS and RSBC survey data were used in the same model. The resulting two variable model for predicting average bag/day included the indices quail/100 miles (October RMCS) and adults/observer (RSBC), (R^2 = 0.940, F = 94.08). The index values quail/100 miles (October RMCS) and total quail/observer (RSBC) comprised the best two variable model for predicting season bag/hunter (R^2 = 0 .919, F = 68.36) and total quail harvest (R^2 = 0.896, F = 51.56). Predicting formulas for the above models are

$$\text{average bag/day} = 1.415 + 0.211\ (X_1) + 0.018\ (X_2)$$

$$\text{season bag/hunter} = 6.835 + 1.460\ (X_1) + 0.034\ (X_3)$$

$$\text{total harvest} = 866{,}918 + 243{,}766\ (X_1) + 6{,}191\ (X_3)$$

where: X_1 = quail/100 miles (October RMCS)
X_2 = adults/observer (RSBC)
X_3 = total quail/observer (RSBC)

Substantial improvement in the ability to predict bobwhite harvest parameters may be realized through the use of predictive formulas (Schwartz 1974a). Attempts to estimate harvest parameters using long-term means resulted in average annual errors of 20.0 percent, 18.5 percent, and 21.5 percent for average bag/day, season bag/hunter and total harvest, respectively. Average annual errors of the predicted values (using the multiple regression formulas) from the mail survey harvest parameter estimates were 4.3 percent, 6.5 percent and 8.9 percent for average bag/day, season bag/hunter and total harvest, respectively. Thus an improvement of 15.7, 12.0 and 12.6 percent is achieved for estimates of average bag/day, season bag/hunter and total harvest, respectively, when compared to use of long-term means for prediction purposes.

CONCLUSION

For years wildlife managers have tried to accurately monitor quail populations and predict harvest and harvest rates (Bennett and Hendrickson 1938, Bennett 1951, Kozicky et al. 1956, Preno and Labisky 1971, Ellis et al. 1972). In Kansas, a variety of survey techniques have been used both experimentally and on a continuing basis. These include April roadside counts by Fish and Game personnel counting coveys and individual birds; standardized whistle count routes run during June, July, and August; counts made by rural mail carriers during April, July, and October; and random quail observations (random summer brood count) made by Fish and Game personnel during July and August. Harvest

Table 13. Correlation coefficients resulting from testing between bobwhite population indices obtained from the random summer brood count and hunter performance data from the statewide harvest mail survey in Kansas, 1963-1980.

Harvest Parameters	Random Summer Brood Count								
	Broods/ Obs (18)	Young/ Obs (18)	Males/ Obs (18)	Females/ Obs (18)	Adults/ Obs (18)	Total Q/ Obs (18)	Young/ Brood (18)	Young/ Adult Female (18)	Young/ Adult (18)
Avg Bag/ Day	0.837**	0.849**	0.903**	0.907**	0.909**	0.889**	0.637**	N.S.	N.S.
Season Bag/Hunter	0.850**	0.842**	0.831**	0.875**	0.854**	0.868**	0.586**	N.S.	N.S.
Total Harvest	0.724**	0.695**	0.697**	0.740**	0.719**	0.721**	0.460S	N.S.	N.S.

(N) = Number of years compared
S = P < 0.10
* = P < 0.05
** = P < 0.01
N.S. = P > 0.10

information has been collected using a mail survey of hunting license buyers and random field bag checks conducted by Fish and Game personnel.

Of the population surveys tested, the RMCS and RSBC provide the best parameters. These two techniques have been continued in Kansas because of their relationship to harvest statistics and their cost efficiency.

The RMCS involves only a limited number of Fish and Game personnel to perform the mailing of survey cards and tabulation, analysis, and reporting of the data. During each survey period 520-550 rural mail carriers return useable data and report on quail seen while driving approximately 250,000 miles along country roads during each survey period.

The RSBC survey is performed by Fish and Game personnel who record quail observations during their normal work activities. There is little additional mileage or personnel time incurred.

The statewide mail harvest survey is still performed by the Kansas Fish and Game Commission and is preferred over the random bag check since it too involves few personnel and has proven to be capable of collecting useable harvest statistics of dependable precision with minimum cost.

Through this analysis of population and harvest statistics, we are now capable of accurately predicting and forecasting hunter performance and expectations for the subsequent hunting season.

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EFFICIENCY OF DOGS IN LOCATING BOBWHITES[1]

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Abstract: The efficiency of dogs in locating bobwhites (*Colinus virginianus*) was studied on Tall Timbers Research Station, Leon County, Florida. Numbers of bobwhites present on two study areas were determined in six different years with the Lincoln Index method. Numbers of bobwhites found on bird dog censuses and numbers of bobwhites flushed while methodically hunting the study areas were recorded for comparison with Lincoln Index data. Numbers of bobwhites found with both methods involving bird dogs were substantially less than those numbers determined with the Lincoln Index census technique.

We examined the efficiency of dogs in locating bobwhites (*Colinus virginianus*) in order to (1) evaluate the use of dogs for censusing bobwhites and (2) determine the percentages of bobwhites found by hunters with dogs in relation to the number of bobwhites actually present. Quail population levels were estimated using the Lincoln Index method (Davis 1963, Kellogg et al. 1972). These population numbers were used as a base for comparison.

METHODS

This investigation was conducted at Tall Timbers Research Station, a 1300 ha area located in Leon County, Florida, in the Tallahassee Red Hills sub-region of the Coastal Plain. It is an area of rolling hills and open pine woodland, scattered fields, and some hardwood thickets in wetter areas. Two study sites, one of 202 ha and the other of 210 ha, were used. Almost all of the woodland portion of the study areas was burned annually in late winter. Small cornfields made up approximately 17 percent of the study areas (average = 0.9 ha each). The study areas are described in more detail by Smith (1980).

Bird dog censuses were made in February of 1976, 1977, and 1979. Each party of two men and two dogs was assigned a certain portion (approximately 40 ha) of one study site to cover and was instructed to see that dogs or men went within at least 25-30 m of all points on the property. Approximately 15 ha were covered per hour by a party. This would be considered intensive coverage by most hunters. Personnel were instructed to count birds in each covey as the covey flushed, to mark the location at which they landed, and to assure themselves that the birds were not counted twice during the census. This was not as difficult as it might seem, since a covey that has been flushed recently is usually spread out and does not flush the second time from a small area. There were five repetitions of the study, giving five sets of data for comparison with the Lincoln Index census figures.

Methodical hunting of both 200+ ha study areas was conducted annually each February from 1976 through 1982. There were 50 repetitions of hunts over the study sites, and in each year each study site was hunted three to five times. Successive hunts over the same ground were 24 to 72 hours apart. The information on hunting was gathered during the Lincoln Index census when birds were shot to get banded/unbanded ratios. To determine the number of birds left on the study area after

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each hunt, all birds in the bag, shot down and lost, or feathered were subtracted from the Lincoln Index estimate of total population.

There was very little difference in method between the bird dog census studies and hunting operations, except that hunting parties occasionally had as few as one hunter and as many as three. Dogs ranged in number from one to four, the usual situation being two. Hunters were asked to count number of birds on a covey rise and to avoid recounting the same birds if they were flushed the second time. In this portion of the study, hunters often pursued singles after a covey rise but were required to cover the entire area thoroughly. Most often hunters were not permitted to kill more than two to four birds per covey. A wide variety of dogs and hunters was used, but at least one person and one dog in each party was an experienced quail hunter.

RESULTS

Table 1 compares numbers of birds found on the bird dog census and numbers of birds actually present as determined by the Lincoln Index census method. Numbers of quail found on bird dog censuses averaged 53 percent of Lincoln Index population estimates and ranged from 46 percent to 68 percent.

Table 2 shows the numbers of birds found with dogs while hunting over the study areas. Numbers of quail flushed while hunting averaged 40 percent of Lincoln Index population estimates and ranged from 17 to 71 percent. The Kruskal-Wallis test on the proportion of bobwhites found during first, second, third, and fourth/fifth hunts disclosed significant differences ($P < 0.05$). The proportion of birds found declined with succeeding hunts. The numbers of birds found in the morning by hunting parties were compared to the numbers of birds located in the afternoon. A paired t test disclosed a tendency for finding more bobwhites in the afternoon than in the morning ($t = 1.944$; $t_{0.10} = 1.943$; $df = 6$).

Table 1. Numbers of bobwhites found during bird dog census compared with Lincoln Index estimates of populations on two study areas.

Year	Site	Lincoln Index Estimate	Number Bobwhites Found	Percentage of Bobwhites Found
1976	1	461	248	54
1977	1	335	225	67
1977	2	134	91	68
1979	1	501	230	46
1979	2	502	239	48

Table 2. Numbers of bobwhites found by hunters compared with Lincoln Index estimates of populations on two study areas from 1976 through 1982.

Year	Study Site	Repetition	Lincoln Index Estimates	Number Found	Percent Found
1976	1	1	461	191	41
		2	418	92	22
		3	394	73	19
		4	377	87	23
		5	366	143	39
	2	1	222	117	53
		2	203	71	35
		3	187	36	19
1977	1	1	335	123	37
		2	305	160	52
		3	272	167	61
	2	1	134	70	52
		2	115	65	57
		3	104	63	61
1978	1	1	366	224	61
		2	328	232	71
		3	299	136	45
	2	1	204	113	55
		2	187	99	53
		3	168	54	32
1979	1	1	501	212	42
		2	467	244	52
		3	429	148	34
		4	403	88	22
	2	1	502	247	49
		2	448	193	43
		3	423	178	42
		4	385	112	29
1980	1	1	577	241	42
		2	537	184	34
		3	496	194	39
	2	1	544	134	25
		2	514	202	39
		3	481	137	28
1981	1	1	625	278	44
		2	576	213	37
		3	543	193	36
		4	510	161	32
	2	1	360	182	51
		2	317	176	56
		3	286	122	43
1982	1	1	303	154	51
		2	263	112	43
		3	237	86	36
		4	218	37	17
		5	214	84	39
	2	1	217	92	42
		2	198	103	52
		3	180	109	61
		4	155	82	53

DISCUSSION

The use of bird dogs for census work appears to yield more variable results than does a walk census as described by Dimmick (1982). We suggest that this is related to (1) adding the dog as another variable and (2) the less methodical coverage of study areas when using dogs. Data gathered by actual hunting parties show an even wider range of percentages of birds located in relation to numbers present. In this situation we added the extra task of shooting and made coverage of the area even less methodical. The percentage of birds found by hunters was normally distributed about the mean of 40 percent (Figure 1).

Analysis of information in Table 2 revealed a general decline on successive hunts in percentage of birds found in relation to numbers of birds present. The average percentage of birds found declined from 46 percent on first hunts to a 32 percent average on fourth/fifth hunts over the same area. Unpublished information from radio-telemetry studies on Tall Timbers Research Station suggests that bobwhites quickly adopt evasive techniques when hunted regularly. In examining the success of morning hunts as opposed to afternoon hunts, we found that in five of the seven years more birds were found per hunting hour in the afternoon than in the morning. Approximately 20 percent more bobwhites were found per party hour afield in the afternoon than in the morning. Hours hunted in the morning usually fell between 0900 and 1200, and hours hunted in the afternoon fell between 1530 and 1830.

In summary, dogs are often not as efficient as their owners might think in locating birds. When hunting an area similar to our study sites in a rigorous and methodical manner, one should probably expect to find approximately 40 percent of the coveys actually present on the area. In comparing this type of hunting to typical hunters' methods, we suspect that most hunters spend a great part of their time hunting only areas that they think will be most productive. By hunting the most productive spots they probably flush more birds per hour of hunting than one would by methodically hunting the entire area. A person methodically hunting an entire area, however, will find a greater percentage of the birds that are actually present on the area.

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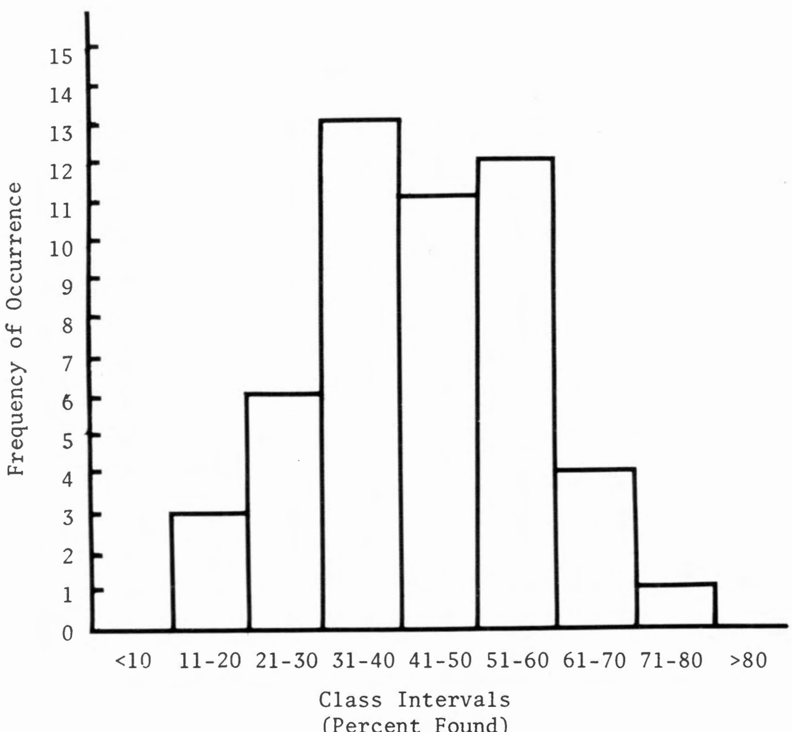

Fig. 1. Frequency distribution of the percentage of bobwhites found by hunters.

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A 10-YEAR STUDY OF BOBWHITE QUAIL MOVEMENT PATTERNS[1]

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Abstract: The movement patterns of 676 bobwhite quail (*Colinus virginianus*) on two study areas on Tall Timbers Research Station in northern Florida were studied during a 10-year period. Eighty-six percent of the quail moved no more than 400 m from their first documented location in a one- to five-year period. Ninety-eight percent moved less than 800 m. Movements greater than 1,000 m occurred but were rare. There were no substantial differences in the annual movements of males and females or immatures and adults; however, the few birds which made longer movements (>800 m) tended to be immature males. The average distance an individual quail moved during a two-week shooting period was greater than the distance moved during the preceding two-week trapping period, but the average difference was only 82 m and therefore insignificant from a practical viewpoint. Movements during shooting averaged 150 m and were not extensive enough to force quail off the study area. Egress and ingress were minimal and approximately balanced. The population was much less mobile than bobwhite populations in other portions of the species' range.

Movements of animals can influence a population as drastically as natality and mortality. Therefore, knowledge of the movement patterns of a wildlife population is essential to the understanding of population dynamics and has practical implications for management. Management studies of bobwhite quail (*Colinus virginianus*) have been underway at Tall Timbers Research Station (TTRS) in Leon County, Florida, since 1970. The purpose of the present study was to investigate the movement patterns of the TTRS bobwhite populations. Specifically, the objectives were to determine (1) year-to-year movements, (2) movements during trapping and shooting periods, and (3) egress and ingress.

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STUDY AREAS

Tall Timbers Research Station consists of approximately 1,300 ha in northern Leon county, Florida, approximately halfway between Tallahassee, Florida, and Thomasville, Georgia. Tall Timbers lies within the Tallahassee Red Hills subregion of the Coastal Plain, characterized by a mature topography of rolling hills with gentle to moderate slope and hilltop elevations of 60 to 90 m above sea level (Hendry and Sproul 1966). Soils are generally well-drained sandy or sandy loam topsoils overlying loamy subsoils. The climate is temperate with mean annual temperature of 20 C and annual rainfall between 79 and 264 cm [mean ($\bar{x}$) = 155 cm]. Winter and summer are typically

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wet seasons, but periods of several weeks without rain are common.

Approximately 85 percent of TTRS is in woodland, primarily open stands of mature loblolly (Pinus taeda) and shortleaf pine (P. echinata) interspersed with live oak (Quercus virginiana). The woodlands are burned in February or March each year, and a herbaceous cover rich in legumes such as partridge pea (Cassia spp.), native lespedezas (Lespedeza spp.), and beggarweeds (Desmodium spp.) develops in the spring. Fields and fire ecology plots are protected from burning by an extensive network of fire lanes plowed each year (Kellogg and Doster 1971, Kellogg et al. 1970, 1972). Tall Timbers Research Station has not been intentionally managed for quail since 1964, but land management practices have been relatively favorable to quail. The bobwhite population is protected from all hunting except that associated with the management study.

After a preliminary census of the bobwhite population at TTRS in 1969, two study areas were selected for comparison of management techniques: a North site of 204 ha and a South site of 212 ha (Figure 1). The sizes of the areas were dictated by the manpower available to conduct the study. The sites are separated by a two-lane highway and at the nearest point are approximately 75 m apart. Based on the 1969 population estimates, the study sites had approximately equal densities of quail.

In the springs of 1969, 1970, and 1971, fields on the North site were planted in corn, but no planting was done on the South site. In 1972, 1973, and 1974, corn was planted on the South site, but not the North. Thereafter, for the duration of the study, fields on both sites were planted. Corn was harvested with mechanical pickers in the fall of each year. No herbicides or pesticides were used. Further descriptions of the area are available (Beadel 1962, Kellogg and Doster 1971, Kellogg et al. 1970, 1972, Smith 1980).

METHODS

Beginning in 1970 and continuing through 1979, bobwhite quail at TTRS were censused annually. Quail were trapped and banded in late January or early February of each year. The trapping period lasted from 6 to 14 days. Funnel-type quail traps similar to those described by Stoddard (1931) were placed in sites considered to be frequently used by quail. Approximately one trap per 2-2.5 ha was used. Traps were weighted with bricks and covered with dead vegetation to protect captured birds from raptors and other predators. Cracked corn was used as bait. There was no prebaiting of trap sites.

Although many trap sites were used repeatedly throughout the study, trap sites and total number of traps varied somewhat from year to year. When trap sites were relocated, traps were moved a maximum of 60 to 75 m. In 1971, 1975, and 1976, additional traps were placed outside the boundaries of the study areas to ascertain the extent of movement off the study sites. The areas in which extra trapping was conducted are indicated on the map in Figure 1. Extra trapping was concurrent with trapping on the study sites.

When captured for the first time in a given year, quail were sexed, aged, and banded with a number-coded size 7 aluminum leg band. The identification numbers of any bands from previous years were recorded. Adults had completed at least one post-nuptial molt and were at least 1.5 years old. Juveniles were six to eight months old at the time of capture.

Immediately after banding, all birds were released at the site of capture except during an additional trapping period in 1975 when, after censusing was completed, birds were trapped and removed from the South study site to intentionally reduce the population to one bird per 4 ha. Trapping was terminated when the percentage of recaptured quail was 70-90 percent for several days.

Collection by shooting began within a week after trapping ended and lasted from four days to two weeks. Collection parties of two or three hunters using two or three dogs were assigned a portion of the study area to cover each day. Both study sites were hunted until approximately 20 percent of the population had been collected.

Hunters recorded the sex and age of all collected birds and the identification number of any bands. Precise locations at which birds were shot were mapped by hunters in 1977, 1978, and 1979. In several years, parties hunted in areas outside the study site (at least 45 m away from the boundaries) to monitor movement of banded quail off the study areas. In 1973, 1975, and 1976, extra shooting was conducted on the areas where extra trapping was done outside the boundaries.

Year-to-Year Movements

Movement records were compiled from the trapping and banding data for all quail captured at least two years during the study. A compsite map of all traps enumerated in the movement records was constructed using individual maps of trap locations from each of the 10 years of the study. An electronic digitizer was used to assign Cartesian coordinates to each trap site on the composite map.

The straight-line distance between two traps at which a bird was captured represented the minimum distance moved (MDM) during the period between winter captures. Actual distance moved by a bird could have been much greater. The MDM was calculated for all possible combinations of trap sites in an individual record. Thus, the movement record of a quail captured four consecutive winters yielded three 1-year MDM, two 2-year MDM, and one 3-year MDM (Figure 2).

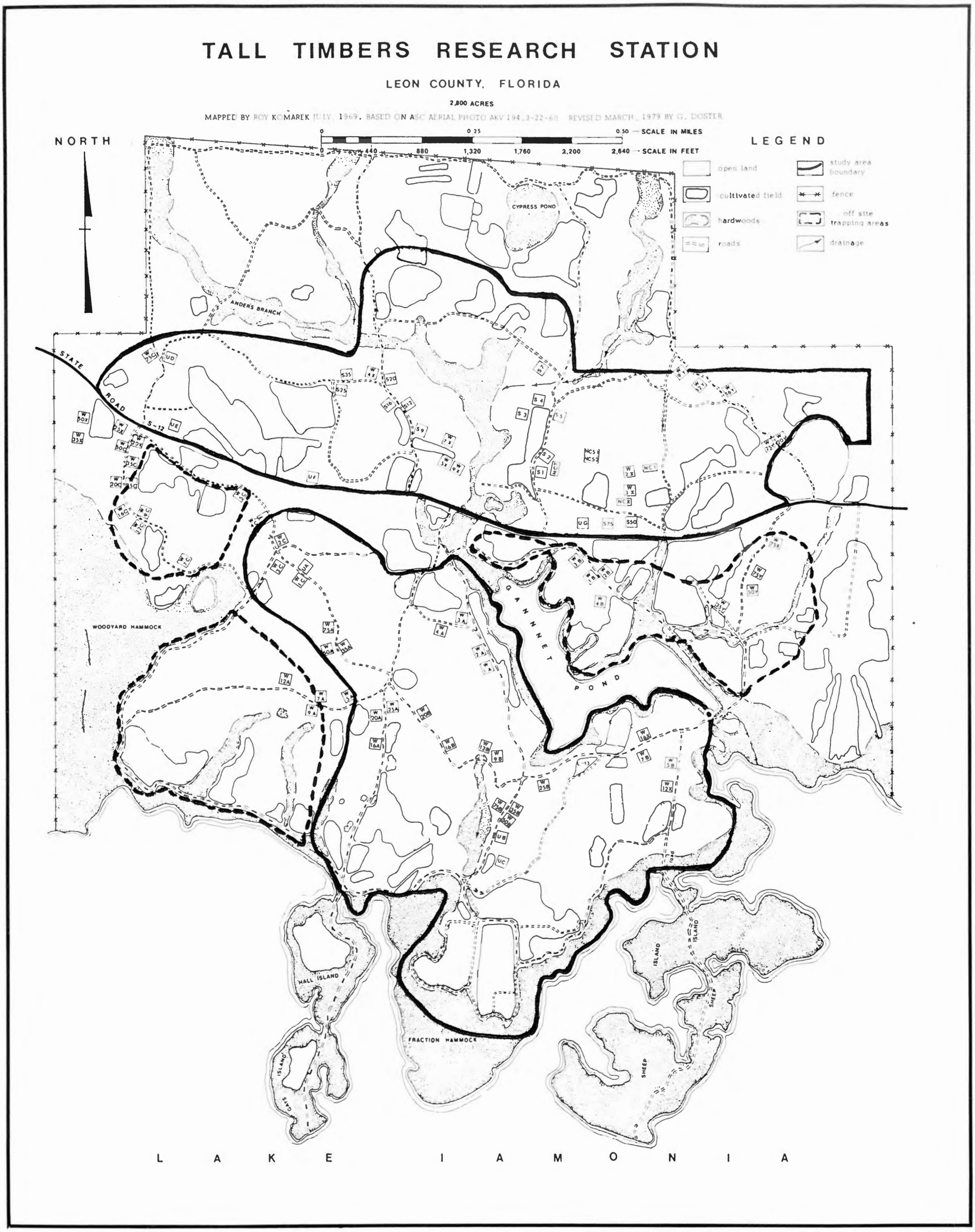
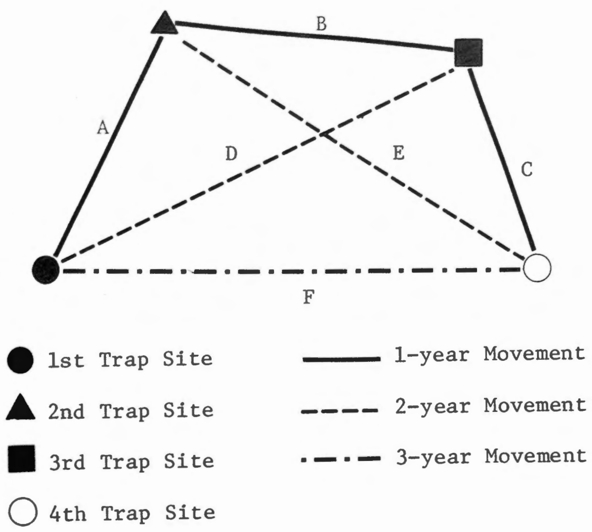


Fig. 1. Map of Tall Timbers Research Station showing North Study Site, South Study Site, and off-site trapping areas.



1-year MDM: A, B, C

2-year MDM: D, E

3-year MDM: F

CDIST = A + B + C

Fig. 2. Diagram and description of the various distances calculated for a quail captured four consecutive winters.

For birds captured three or four consecutive winters, straight-line distances between annual captures were summed. This cumulative distance (CDIST) represented the best estimate available of the actual distance moved by a quail from first to last capture (Figure 2).

Two approaches were used to analyze MDM data. In the first approach, all year-to-year movements by an individual bird were included when calculating descriptive statistics [$\bar{x}$, Standard Deviation (SD)]. In the second, only one movement for each bird, MDM from first to last trap site, was used in calculations.

A paired t-test (Ostle and Mensing 1975) was used to determine the significance ($P \leq 0.05$) of the difference between two consecutive one-year movements of an individual quail. One-year movements were subjected to an analysis of variance (ANOVA) to determine whether significant differences ($P \leq 0.05$) were attributable to year, age, sex, or study site. The design was unbalanced, with an unequal and disproportionate number of observations in subclasses; therefore, a linear least square analysis was used to perform the ANOVA (Ostle and Mensing 1975). Duncan's (1955) multiple range test was used to compare means of significant main effects and a selected interaction term.

Movement during Trapping and Shooting Periods

Records of movements within the trapping period were compiled for all quail trapped at least twice during the trapping periods in 1977, 1978, and 1979. An individual retrap record consisted of the sequence of trap sites at which a bird was captured within a trapping season. The distance from first to last trap site in a retrap record was assumed to represent the distance moved by a bird during the trapping period (TDIST).

Distances moved during shooting (SDIST) were calculated for all banded birds shot during 1977, 1978, and 1979. The straight-line distance between the site at which a bird was shot and the trap site at which it was last captured in the preceding trapping period was assumed to represent SDIST. A paired t-test was used to determine the significance ($P \leq 0.05$) of the difference between SDIST and TDIST for birds retrapped and shot within the same census period.

Additional Movement Records

In addition to the movement records obtained from trapping and shooting, other records were collected that, while not providing conclusive information, provided insight into the egress and ingress patterns of the population. Movements were analyzed for those banded birds that changed from one study site to the other between winters or were shot or trapped outside the boundaries. Approximate locations at which banded quail were recovered on adjacent properties were plotted on a Grady County, Georgia, or Leon County, Florida, map, and distances moved since last capture were measured.

Population Estimates

Chapman's (1951) modified Lincoln Index was used to estimate the quail population on each study site at the beginning of winter trapping each year. Population sizes after censusing were calculated by subtracting all known losses during the census from the population estimates derived from the banding returns. Pre- and post-census densities of quail on each study site each year were calculated. Correlation analyses were used to determine the significance ($P \leq 0.05$) of the relationships between mean annual movement and quail densities.

RESULTS AND DISCUSSION

Distances Moved from Year to Year

During the 10 years of censusing, 6,033 quail were banded one or more times, and of these, 574 were banded for two or more years. The trapping records of these 574 TTRS quail yielded 710 MDM ranging in duration from one to five years. Sample means and frequency distribution of MDM obtained by using only one movement per bird were similar to those obtained when all possible year-to-year movements by a bird (Table 1) were included in the analysis (Smith 1980). Further discussion of distances moved by TTRS quail is based on the total number of MDM recorded, irrespective of duplication of movements by individuals.

Five hundred eighty-four 1-year MDM were obtained from the trapping records of 529 quail (Table 1). Approximately 88 percent of the one-year MDM were less than 400 m. Ninety-eight percent of the birds moved no more than 800 m from their initial trap site in a year's time.

Data from this study and Simpson's (1976) were obtained in the same general region and on study areas of approximately the same size. The frequency distributions of one-year MDM were very similar, with more than 96 percent of both populations moving no more then 800 m in a one-year period. A greater percentage of TTRS quail remained within 400 m of the initial trap site, which suggested that the TTRS population was even more sedentary than Simpson's.

Differences in winter-to-winter movements of TTRS and Wisconsin quail (Kabat and Thompson 1963) were substantial. A much greater percentage of the Wisconsin quail moved more than 800 m, and though no statistical test could be made, the mean distances moved were obviously different. None of the TTRS annual movements recorded in trapping exceeded 1,600 m, although 33.6 percent of the Wisconsin movements did. Most birds moving distances greater than 1,600 m at TTRS probably would have moved off the study site. Movements between 800 and 1,600 m were easily possible on the combined study areas, yet only 1.7 percent of the movements were within that category. If so few annual movements at TTRS were between 800 and 1,600 m, then probably even fewer were longer than 1,600 m. Approximately the same percentage of Texas (Lehmann 1946) and TTRS quail moved no more than 800 m, but one-year movements in the TTRS population were more concentrated in the "less than 400 m" category. Therefore, one-year MDM of TTRS quail were more limited than those of quail in Wisconsin and Texas.

Several investigators have obtained year-to-year quail movements incidental to studies of seasonal movements. Such studies have been generally short-term, and the number of annual movements recorded were few. Murphy (1951) reported eight annual movements for Missouri quail ranging from 400 to 2,640 m, five of which were less than 800 m. In another study on the same area, seven of nine quail moved less than 800 m in one year (Lewis 1952). Extremely long one-year movements ($\bar{x}$ = 8,184 m) were recorded for two quail in a low density Indiana population (Hoekstra and Kirkpatrick 1972). Most of the Wisconsin quail trapped 10 to 16 months after banding moved less than 800 m (Errington 1933). Stoddard's (1931) movement analysis of south Georgia-north Florida quail included movements of various durations. His results were generally similar to those of this study in that the movements he reported were less than those of quail in other regions.

Two-year movements further substantiated the sedentary nature of TTRS quail. Eighty percent

Table 1. Summary of 710 winter-to-winter movements of bobwhite quail at Tall Timbers Research Station, 1970-1979.

Distance moved (m)	1 - Year Number(%)	2 - Year Number(%)	3 - Year Number(%)	4 - Year Number(%)	5 - Year Number(%)	Total Number(%)
0 - 200	335 (57.4)	45 (42.9)	2 (11.1)	1 (50.0)		383 (53.9)
201 - 400	178 (30.5)	39 (37.1)	9 (50.0)		1 (100.0)	227 (32.0)
401 - 600	50 (8.6)	14 (13.3)	4 (22.2)			68 (9.6)
601 - 800	11 (1.9)	6 (5.7)	1 (5.6)			18 (2.5)
801 - 1,000	3 (0.5)					3 (0.4)
1,001 - 1,200	3 (0.5)	1 (1.0)	1 (5.6)	1 (50.0)		6 (0.8)
1,201 - 1,400	3 (0.5)		1 (5.6)			4 (0.6)
1,401 - 1,600	1 (0.2)					1 (0.1)
TOTAL	584 (100.1)	105 (100.0)	18 (100.1)	2 (100.0)	1 (100.0)	710 (99.9)
Average MDM	214	267	425	630	249	228
Standard Deviation	196	185	290	693		203
Range	0 - 1,478	0 - 1,069	71 - 1,250	140 - 1,120		0 - 1,478

of the 2-year movements were less than 400 m, and 99 percent were less than 800 m (Table 1).

The mean of three-year MDM was greater than the means of the one-and two-year MDM (Table 1), and 39 percent of three-year movements were greater than 400 m. However, the number of three-year movements was probably too small to conclude that three-year movements were actually greater. Four-and five-year movements were even fewer. Two males, first captured as immatures, were recaptured four years after initial banding. One moved only 140 m from the original trap site; the other moved 1,120 m. A third male, banded as a immature, was recovered five years after the first capture only 249 m from the original trap site. Movements of long duration are interesting but probably contribute little to the movement patterns of the population as a whole since so few birds survive to make such movements.

Differences in Movement among Yearly Intervals

Although there was no clear pattern in the mean differences, there was a general tendency for longer movements in the later years of the study (Table 2). Comparison of sample means raised a fundamental question: What magnitude of mean difference was biologically or practically significant? Average MDM for the first interval, 1970-1971, was statistically different from all other means, yet the difference between means of the first two intervals was only 52 m. Such a slight difference in the average distance moved by quail during those two years was not practically different. Maximum mean difference between years was 227 m. A difference of this magnitude probably was indicative of a meaningful difference in the movement of quail during the two intervals, 1970-1971 and 1977-1978.

Changes in habitat over time might have affected movement, but the only major change in land use at TTRS during the years of census was the pattern of corn planting. Corn fields are apparently beneficial to quail (Nevels 1952, Kellogg et al. 1972), but we detected no relationship between the presence of corn fields and movement on a study site. In the years when corn was planted on one study area and not the other, there was no significant difference between mean annual MDM of the two sites. Quail did not move long distances toward the corn fields.

Fluctuations in population size could influence yearly movements. Several investigators have suggested that bobwhite quail in more densely populated areas are less mobile than birds in less densely populated areas (Errington 1941, Errington and Hammerstrom 1936, Urban 1972). Others believed population density and movement were directly related; population pressure forced birds to move (Murphy 1951, Loveless 1958). Present data were sufficient to consider only the relationship between annual movement and winter density.

Yearly estimates of the population size and density on each study site at the time of trapping and after censusing are presented in Table 3. Winter densities on the two study sites differed significantly ($t = 2.98$, $P < 0.02$). Therefore, analyses were performed separately for the North and South study sites. Since only one population estimate per year was obtained for each study site, the effects of year and density

Table 2. Average one-year movements (m) of bobwhite quail at Tall Timbers Research Station for nine yearly intervals.

Interval	Number	Average MDM	Standard Deviation	Range
1970-71	131	142	101	0 - 529
1971-72	134	194	172	0 - 972
1972-73	120	221	230	0 - 1,478
1973-74	46	244	180	0 - 718
1974-75	53	211	160	0 - 519
1975-76	23	334	309	0 - 1,203
1976-77	37	292	248	0 - 1,028
1977-78	14	369	315	65 - 1,391
1978-79	26	295	155	0 - 600
TOTAL	584			

Table 3. Population and density estimates (birds/ha) of bobwhite quail on the North and South study sites at Tall Timbers Research Station, 1970-1979.

Year	Study site[a]	Number at start of trapping period	Standard Error (95% CI)	Density at start of trapping period	Number at end of shooting collection[b]	Density at end of shooting collection
1970	N	1,158	58 (1,044-1,272)	5.6	918	4.5
	S	723	70 (586-860)	3.4	592	2.8
1971	N	1,411	84 (1,246-1,576)	6.9	1,159	5.7
	S	829	59 (713-945)	3.9	684	3.2
1972	N	1,555	73 (1,412-1,698)	7.6	1,220	6.0
	S	608	39 (532-684)	2.9	459	2.2
1973	N	713	33 (648-778)	3.5	526	2.6
	S	742	41 (662-822)	3.5	543	2.5
1974	N	563	39 (487-639)	2.7	410	2.0
	S	426	34 (359-493)	2.0	306	1.4
1975	N	410	28 (355-465)	2.0	304	1.5
	S	355	15 (326-384)	1.7	136	0.6
1976	N	463	35 (394-532)	2.3	367	1.8
	S	228	27 (175-281)	1.1	177	0.8
1977	N	343	29 (286-400)	1.7	261	1.3
	S	138	12 (114-162)	0.6	97	0.5
1978	N	378	35 (309-447)	1.8	295	1.4
	S	213	26 (162-264)	1.0	165	0.8
1979	N	501	37 (428-574)	2.4	385	1.9
	S	504	37 (431-577)	2.4	385	1.8

[a]N = North; S = South.

[b]Number at end of shooting collection = Number at start of trapping period - known losses during census.

could not be separated in the analysis. Any conclusions drawn from the results of those analyses are subject to this qualification.

The relationship between annual movement and population density was investigated by correlating the bobwhite density during a given winter with mean annual MDM from that winter to the next. Density at the time of trapping and mean one-year MDM were negatively correlated. Correlation of the two measures was highly significant on the South study site ($r = -0.73$, $P < 0.02$) and not significant on the North ($r = -0.58$, $P < 0.10$). The correlations between density after censusing and mean annual MDM were similar (South, $r = -0.75$, $P < 0.02$; North, $r = -0.56$, $P < 0.12$). The relationship between winter population density and movement during the preceding year was also evaluated, but the correlation was not significant.

Differences in Movements between Sexes and Age Classes

Some have suggested that male bobwhites tend to move farther than females (Hood 1955, Loveless 1958, Kabat and Thompson 1963), but others found no sex differential in movement (Stoddard 1931, Errington 1933, Murphy 1951, Simpson 1976). Loveless (1958) reported that there was no difference in the spring and summer movements of adult and immature quail, and Simpson (1976) concluded the same about fall movements. Results of this study disclosed slight sex and age differentials in quail movement. Mean one-year MDM was significantly greater for males and immatures (Table 4). Comparisons of mean annual MDM for sexes and age classes revealed that although a statistically significant difference existed, a biological or practical difference did not. The data did suggest, however, that those few birds making extensive movements will most likely be immatures, and probably males.

Patterns and Directions of Movement

The cumulative distance (CDIST) moved between traps for 55 quail captured three consecutive years ranged from 43 to 1,219 m and averaged 415 m (SD = 269 m). A single female captured four consecutive years had a CDIST of 465 m. There was no consistent pattern of movement for bobwhites with consecutive yearly captures. Some tended to move in a straight line away from the initial trap site; however, consecutive movements of other birds formed a more acute angle, resulting in final locations nearer to the initial capture site. Forty-one of the 574 birds giving movement records were trapped the first and last time at the same trap location. Similarly, there were no significant differences in directional (N, S, E, W) movements.

Movement during Trapping and Shooting Periods

Normal movements of TTRS quail might have been reduced during trapping because of the intensive use of baited trap sites. On the other hand, hunting possibly stimulated movement. Rosene (1969) contended that coveys flushed too frequently would move from an area. Errington and Hammerstrom (1936) thought that shooting or other continuous disturbances could cause a covey to relocate within its range but would seldom drive it out of its range altogether.

Distance moved during trapping and shooting periods could be compared for 130 TTRS quail which had been retrapped and later shot during the same census period (1977-1979). Quail were shot 5 to 14 days after being trapped for the last time. For these 130 quail, mean distance moved during trapping (TDIST) was 73 m (SD = 84 m), and mean distance moved during shooting was 155 m (SD = 105 m). For an individual quail, SDIST was significantly greater than TDIST ($t = 7.56$, $P < 0.001$). However, mean difference between SDIST and TDIST was only 82 m, which is insignificant from a practical standpoint.

Additional shooting movement records were available for 102 banded quail shot but not retrapped during the same census period. Thus, SDIST was known for a total of 232 banded quail. Shooting movements ranged from 0 to 544 m, and mean SDIST was 150 m (SD = 104 m). Movements of this magnitude would have caused few birds to leave the study sites. therefore, movement during shooting was concluded to be of little practical importance.

Recoveries of banded birds by parties hunting outside the boundaries also were indicative of the extent to which quail moved off the areas after trapping and during shooting on study areas. Parties hunting in areas more than 45 m away from the study site boundaries recovered no banded birds. However, in 1973, 1975, and 1976, when hunting outside the study sites was more intensive and conducted along the boundaries, banded birds were collected. Shooting in the buffer zone between the study sites in 1973 yielded 39 quail, of which 17 had been banded that year. In 1975, 18 of 43 birds shot outside the study sites were banded, but only 1 of 17 birds shot in 1976 was banded.

Exact shooting locations for the birds were not recorded, so distances moved from last trap to shooting site were not known. However, the majority of banded birds shot off the areas were last captured at trap sites located on the periphery of the study sites. Movements of less than 90 m would have placed all birds except two outside the boundary. One bird moved a minimum of 230 m off the study area, and another, 650 m. The distances moved by these birds probably were not different from those of birds shot on the area. Most likely the covey ranges of these birds overlapped the boundaries, and these quail were shot within their normal ranges.

Table 4. Average one-year movements (m) of bobwhite quail at Tall Timbers Research Station for sexes and age classes.

Variable	Number	Average MDM	Standard Deviation	Range
Age				
Adult	186	177	141	0 - 972
Immature	398	231	215	0 - 1,478
Sex				
Male	339	230	213	0 - 1,478
Female	245	191	168	0 - 1,203

Egress and Ingress

Information on egress and ingress was provided by (1) band returns from birds shot on adjacent properties, (2) shooting outside the boundaries, (3) trapping outside the boundaries, and (4) movements between study sites. During the 10 years of study, only six banded birds were recovered on surrounding properties. The hunting on surrounding properties was intensive enough that if large numbers of TTRS quail moved long distances, then more banded quail would have been collected. Shooting parties intensively hunted TTRS areas outside the study site boundaries several years. Their collections should have detected the presence of banded survivors from the previous year that had moved and remained outside the study sites, but no such birds were collected. Results from trapping outside the boundaries disclosed that very few banded birds were trapped outside the study areas in succeeding years. Similarly, only 9 of 156 birds originally trapped outside the study areas were recaptured the following year on the study sites. The above data indicate that egress and ingress were minimal and generally equivalent. An approximately equal number of birds moved from one study site to the other, which further supported the conclusion of balanced egress and ingress. These conclusions are similar to those of Simpson (1976), who found a very small number of birds moving onto adjacent properties.

Several studies have attempted to assess egress and/or ingress from recapture data. In a Wisconsin population, 42 percent of the birds emigrated from the study area during spring (Buss et al. 1947); in another, 79 percent emigrated (Kabat and Thompson 1963). Extensive spring dispersal occurred in a Missouri population; half the adult birds in a spring population had moved onto the study area since winter (Murphy and Baskett 1952). Another study on the same area found considerable ingress during the spring (Lewis 1954).

Failure to retrap a reasonably high percentage of banded birds has been interpreted as indicating movement of large numbers from the population (Lehmann 1946, Loveless 1958). As Lewis (1952) noted, such a conclusion is questionable since it fails to take into account the high turnover rate in quail. In the present study, 86 percent of the 5,521 banded birds that survived the shooting period at TTRS were never recaptured. It is obvious that the majority of these banded birds did not move off the study sites.

Considered as a whole, the results of this study depict a quail population in which very little movement occurred. The great majority of the population was extremely sedentary. Some birds moved long distances, but the number of birds making such movements was very small. Even when disturbed by shooting activities, quail moved very little. Movement in and out of the study sites occurred but was minimal and generally confined to areas along the periphery of the study sites. Most likely this was normal movement by birds whose ranges overlapped the artificial boundaries. The conclusion consistent with these results is that the banded birds not recaptured disappeared not because they moved, but because they died. Movement of TTRS quail is so limited that movement can be disregarded as a major factor in population dynamics.

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HUNTER SUCCESS AND CRIPPLING LOSSES FOR BOBWHITE QUAIL[1]

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Abstract: During a two-week period each February from 1972 through 1981, bobwhite quail (*Colinus virginianus*) were collected on two study sites consisting of 202 and 210 hectares (505 and 524 acres, respectively). Bobwhites were collected by conventional sport hunting techniques, and records were maintained on several criteria concerning hunter success and crippling loss. During the 10-year study, 108 different hunters using 112 different dogs hunted a total of 3,089 man hours, flushed 15,576 bobwhites, fired 6,820 shots, bagged 2,245 bobwhites, shot down and lost 230 bobwhites, and feathered an additional 385 bobwhites. Bobwhite density ranged from 0.6 to 7.6 bobwhites per ha (0.3 to 3.1/acre). Crippling loss ranged from 15 percent to 29 percent ($\bar{x}$ = 22 percent) of the total annual kill but did not correlate with fluctuations in bobwhite density.

Long-term studies on management and diseases of bobwhite quail (*Colinus virginianus*) have been underway at Tall Timbers Research Station in Leon County, Florida, since 1969. Part of this research has involved the annual harvest of approximately 25 percent of the bobwhites present on each of two study sites consisting of 202 and 210 ha (505 and 524 acres, respectively). Bobwhites were collected by conventional sport hunting techniques, and records were maintained on a number of criteria, including hunting success and crippling loss. Kellogg and Doster (1971) reported the results of the first three years of this aspect of the study. This report provides information from an additional 10 years' data and compares results at different quail density levels.

[1]This study was supported by Tall Timbers Research Station, Tallahassee, Florida, and by an appropriation from the Congress of the United States to the Southeastern Cooperative Wildlife Disease Study, The University of Georgia. Funds were administered and research coordinated under the Federal Aid in Wildlife Restoration Act (50 Stat. 917) and through Contract No. 14-16-0009-78-024, Fish and Wildlife Service, U.S. Department of the Interior.

METHODS

Study site descriptions and collection methods were generally the same as described by Kellogg and Doster (1971). In the present study, however, hunting records were maintained separately for the two study sites. Further description of the study sites, collection techniques, and bobwhite densities is available elsewhere (Kellogg et al. 1970, Kellogg et al. 1972, Smith 1980).

Data for this study were collected during a two-week period each February from 1972 through 1981. Each study site was divided into sections that could be covered thoroughly by a hunting party in two to four hours. All sections of each study site were hunted a minimum of three times during the two-week period. In order to distribute the collection of bobwhites over each study site, hunting parties usually were restricted to killing only two to four birds from each covey found during a hunt. A hunting party normally consisted of two to three hunters using two dogs. During the 10-year investigation, 108 different hunters using 112 different dogs participated. Hunters ranged from novices to well-seasoned veterans, and dogs ranged from puppies in training to older, well-trained dogs. Most hunters used 12 or 20 gauge shotguns, but a few used 16 gauge guns. Many of the same hunters and dogs participated in both this and the earlier study (Kellogg and Doster 1971).

During each hunt, records were kept pertaining to man-hours hunted, number of bobwhites flushed, shots fired, bobwhites retrieved, birds shot down but lost, and birds feathered that kept flying. Crippling loss was the sum of birds shot down but lost plus birds that lost feathers but kept flying after being shot. These birds, added to those actually retrieved, comprised the total kill.

Pertinent data were encoded, entered on computer punch cards, and analyzed using statistical procedures from the Statistical Analysis System (Helwig and Council 1979). Variables were compared using linear regression analyses and correlation coefficients except for testing of trends over time (i.e., in succeeding years of the study) in which case the runs test (Remington and Schork 1970) was used.

RESULTS AND DISCUSSION

Information from both study sites for each year is given in Table 1. Also included in Table 1 for comparative purposes are data from the earlier study by Kellogg and Doster (1971). Results of the two studies are similar, i.e., about three shots were fired for each bird bagged, and one bird was lost to crippling for every three to four bagged.

In addition to the basic question of obtaining a reference value for crippling loss, data obtained during this study afforded insight on several other related questions. First, does the percentage of total crippling loss or either of its components (i.e., percentage down and lost or percentage feathered) vary in relation to bobwhite population density? Analyses did not indicate any relationship between bobwhite density and total crippling loss ($r = -0.08$; $P = 0.74$), birds shot down but lost ($r = 0.13$; $P = 0.58$), or birds feathered ($r = -0.29$; $P = 0.21$). Second, did hunters expend more effort (i.e., were they more successful) at locating downed birds when their chances of finding new coveys were less (i.e., when flushes per hour were low)? Analysis revealed that the percentage of birds down and lost was not related to the number of flushes per hour ($r = 0.18$; $P = 0.45$). Third, with accrued experience (i.e., in succeeding years) were hunters able to reduce the total percentage crippling loss or either of its components? Analyses indicated that the percentage of birds down and lost had a decreasing trend over succeeding years ($P < 0.05$); however, the total percentage crippling loss and percentage feathered did not exhibit trends over time ($P > 0.05$). Fourth, did hunters have variable rates of shooting success (i.e., number of shots per bird retrieved) at different bobwhite densities or at different hunting difficulties (i.e., flushes per hour)? Analyses disclosed that the number of shots fired per retrieved bird was not related to bobwhite density ($r = 0.25$; $P = 0.29$) or flushes per hour ($r = 0.21$; $P = 0.38$).

The information presented herein should be useful to game managers in determining crippling loss and total harvest of bobwhites on private and public lands. Further, since the data were collected in a manner that can be considered reasonably representative of bobwhite hunting (e.g., at various bobwhite densities, over a number of years, for harvest levels ranging from 19 to 39 percent, and by sport hunting methods), the findings should be broadly applicable.

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Table 1. Harvest data for bobwhite quail collected on Tall Timbers Research Station, Leon County, Florida, from 1969 through 1981.

						Crippling Losses					
Year	Site	Bobwhite Density per ha/ac	Man Hours Hunted	Number Flushed	Shots Fired	Shot Down But Lost +	Feathered =	Total Crippling Loss +	Bobwhites Collected =	Total Kill	Shots Per Bird Retrieved
1969 1970 1971[a]	1&2	>2.4/>1.0	572	5,691	2,639	109(10)[b]	157(14)	266(24)	846(76)	1,112	3.1
1972	1	7.6/3.1	246	2,584	1,013	33(8)	49(12)	82(21)	312(79)	394	3.3
	2	2.9/1.2	169	1,134	450	24(13)	22(12)	46(25)	135(75)	181	3.3
1973	1	3.5/1.4	167	983	519	22(10)	26(12)	48(22)	175(79)	223	3.0
	2	3.5/1.4	183	1,434	563	21(9)	31(13)	52(22)	181(78)	233	3.1
1974	1	2.7/1.1	253	1,018	507	14(7)	31(16)	45(23)	150(77)	195	3.4
	2	2.0/0.8	137	527	302	12(8)	19(13)	31(21)	116(79)	147	2.6
1975	1	2.0/0.8	169	546	253	11(10)	18(16)	29(26)	83(74)	112	3.0
	2	1.7/0.7	165	660	341	15(11)	15(11)	30(22)	109(78)	139	3.1
1976	1	2.3/0.9	191	586	285	5(4)	20(17)	25(22)	91(78)	116	3.1
	2	1.1/0.4	139	333	169	9(14)	10(15)	19(29)	47(71)	66	3.6
1977	1	1.7/0.7	147	476	186	3(4)	15(19)	18(23)	60(77)	78	3.1
	2	0.6/0.3	99	161	87	3(7)	6(15)	9(22)	31(78)	40	2.8
1978	1	1.8/0.7	99	622	222	6(6)	16(16)	22(21)	81(79)	103	2.7
	2	1.0/0.4	74	271	116	1(2)	7(13)	8(15)	44(85)	52	2.6
1979	1	2.4/1.0	145	765	331	9(7)	18(13)	27(20)	108(80)	135	3.1
	2	2.4/1.0	141	737	329	13(9)	18(13)	29(22)	108(78)	139	3.0
1980	1	2.8/1.1	146	752	346	13(8)	24(16)	37(24)	116(76)	153	3.0
	2	2.6/1.1	144	623	255	2(2)	15(14)	17(16)	88(84)	105	2.9
1981	1	3.3/1.3	160	884	321	10(6)	14(9)	24(16)	130(84)	154	2.5
	2	1.8/0.7	115	480	225	4(4)	11(11)	15(15)	82(85)	97	2.7
TOTALS (1972-1981)			3,089	15,576	6,820	230(8) [2-14][c]	385(13) [9-19]	615(22) [15-29]	2,245(78) [71-85]	2,860	3.1 [2.5-3.6]
GRAND TOTALS (1969-1981)			3,661	21,267	9,459	339(9)	542(14)	881(22)	3,093(78)	3,974	3.1

[a]Reported by Kellogg & Doster (1971)
[b]Number in parentheses is % of total kill
[c]number in brackets equals range

HARVEST RATES AND EFFORTS OF AVID QUAIL HUNTERS IN EAST CENTRAL MISSISSIPPI

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Abstract: Six avid quail hunters had an average daily harvest rate of 6.39 (4.97-8.55) and average seasonal harvest of 298 (116-530); they averaged 47 (28-60) hunts or days afield per year for a period of 2-10 years. The avid hunters averaged three to four hunts per week, and the hunts lasted three to four hours. Two hunters often had hunting guests, and the total season harvest by guests averaged 117 (63-211) with one hunter and 121 (56-178) with the other hunter. A seventh avid quail hunter usually had quests, with an average hunting party of 2.45; they harvested an average of 449 (388-510) quail per year over a two year period. Quail harvested per hour of effort ranged from 0.95 to 2.2. Harvest rates and efforts of avid quail hunters were much greater than those of average quail hunters depicted in hunter mail questionnaire surveys.

Wildlife management includes gathering information on hunter harvest rates and effort, and this information has important biological, educational, and administrative values (Guynn et al. 1977). Several state wildlife agencies in the Southeast use a mail survey to obtain information on hunter harvest rates and effort, including data on bobwhite quail (*Colinus virginianus*) hunters (Steffen 1981). Published information on quail harvest rates and efforts represents "average" quail hunters. This study was undertaken to document the harvest rates and efforts of avid quail hunters (bird hunters) in east central Mississippi.

We acknowledge the information contributed by the avid quail hunters. We also extend our gratitude to Mississippi Department of Wildlife Conservation personnel who assisted.

METHODS

Hunting records were obtained from seven avid quail hunters, six who have hunted quail for over 10 years and one who has hunted quail for five years. All hunters trained their bird dogs and used from two to five dogs. Hunters recorded information regarding a hunt immediately after each hunt. A hunt (effort) was considered as any part of or all of a day afield. Several hunters recorded the time (hours) spent on each hunt.

Most quail hunting was conducted around edges of soybean fields and in surrounding old fields and forests in Holmes, Attala, Webster, Clay, Oktibbeha, and Lowndes counties, Mississippi. The quail hunting season in Mississippi extends from Thanksgiving Day through the last day in February (about 94 days), and the daily bag limit is 12.

RESULTS

The average daily harvest for six of the hunters was 6.39 (4.97-8.55) for a period of 2-10 years (Table 1). Seasonal harvest averaged 298 (116-530), and these hunters averaged 47 (28-60) hunts or days afield. During the season when the highest seasonal total for an individual (530) was attained, this hunter averaged 10.7 quail per hunt. Avid quail hunters made three to four hunts per week, and the average hunt lasted three to four hours.

Hunters number 1, 2, 4, and 6 usually hunted alone, but hunters 3 and 5 usually had hunting guests. Total quail harvest by all guests combined averaged 117 (63-211) with hunter number 5 and 121 (56-178) with hunter number 3. A seventh avid quail hunter usually had guests, and during the 1979-1980 season, this hunter and guests (average 2.55 people) harvested 510 quail on 34 hunts (15 quail per hunt). Total effort was 86.7 hours with a harvest rate of 5.9 quail per man-day afield. In the 1980-1981 season, this same hunter and guests (average 2.35 people per hunt) made 26 hunts, spent 61.1 hours afield, and harvested 388 quail, which was 14.9 quail per hunt or 6.35 quail per man-day afield.

One hunter harvested 0.95 quail per hour of effort, which was about the same harvest rate (1 quail/hour) estimated by another hunter. A third hunter averaged 2.2 quail per hour of effort in a season when 432 quail were harvested. This hunter obtained the daily limit (12) of quail on 14 hunts during the season.

DISCUSSION

Many factors affect harvest rates of quail, including hunter effort, experience, and shooting skills; dog training and experience; number and behavior of quail; and hunting conditions (vegetation and weather). In this study, sample size was small and the information came from only one region of Mississippi. However, we believe the information from seven avid quail hunters, who by our definition hunt quail 28+ days and harvest 100+ quail per season, represents avid quail hunters throughout Mississippi and probably other southern states where the bobwhite quail is common.

Harvest rates and efforts of avid quail hunters varied, but were greater than the "average" quail hunter depicted in mail surveys. Mail surveys in Mississippi in 1973, 1977, and 1981 revealed that the average quail hunter bagged 24.7 quail per season and 3.18 quail per hunt (day afield) and hunted an average of 7.72 days per year (Quisenberry 1974, Guynn et al. 1977, Steffen 1981). Data obtained from mail surveys in Alabama for the 1979-1980 and 1980-1981 seasons were similar: 22.7 quail harvested per season, 2.86 quail bagged per day, and 7.91 hunting days per season (Kelly 1980, 1981). Five years' (1967-1978) data from mail surveys in Louisiana found that quail hunters averaged 16.6 quail per season and 2.36 per hunt (effort) and hunted 6.96 days per season (Hunter 1981). In Louisiana from 1975-1979, Prickett (1981) selected and surveyed quail hunters associated with quail clubs or field trial groups. These hunters had an average seasonal harvest of 13.1 and a daily average of 3.1 and hunted an average of 4.4 days per season.

Avid quail hunters in Mississippi harvested about one to two quail per hour of effort. Exceptionally high harvest rates of 2.6 and 2.7 quail per hour were recorded by hunters in Mississippi and Alabama on young loblolly pine (*Pinus taeda*) plantations (Hurst 1978). Perkins (1952) found that the average quail hunt in cut-over longleaf pine (*P. palustris*) forests of southwest Louisiana lasted 4.42 hours, and an average of 4.74 quail was harvested per hunt (1.07/hour). A harvest rate of 3.6 quail per hunter per hour was recorded on one intensively managed quail plantation and 2.2 on another in central Georgia (letter dated 9 May 1978 from R. C. Simpson, Georgia Department Natural Resources, Albany, GA).

Information gathered from mail surveys represents harvest rates and efforts of "average" quail hunters. The results are misleading due to the great variation and effects of averaging data on effort and harvest. If the questionnaire data were plotted by effort, the differences in effort and harvest would become apparent given a large enough sample size. Mail surveys should attempt to classify quail hunters by effort and harvest. Combining avid quail hunters, who average 100-500 quail per season, with hunters who harvest quail while hunting other species distorts the results.

Table 1. Harvest rates and efforts of avid quail hunters in east central Mississippi.

Hunter Number	Yrs. Data Collected	Harvest: Daily Avg.	Harvest: Seasonal Avg.	Harvest: Seasonal Range	Effort[a] Avg.	Effort[a] Range
1	2 (1979-81)	4.97	288	245-332	58	56-60
2	2 (1979-81)	7.76	427	424-430	55	55-57
3	3 (1978-81)	4.83	191	116-245	39	34-44
4	4 (1977-81)	8.55	424	304-530	52	49-56
5	10 (1971-81)	5.33	238	168-325	45	36-52
6[b]	10 (1966-76)	6.88	220	196-324	32	28-36
7[c]	2 (1979-81)	6.12[d]	449	388-510	30	26-34

[a]Days hunted (afield), recorded as any part of or all of a day.
[b]This hunter scheduled his efforts through mid-January, then did not hunt much thereafter.
[c]Data for a hunting party, average 2.45 hunters per hunt over 2 seasons.
[d]Harvest per man-day afield

It was apparent that mail surveys do not represent avid quail hunters.

The number of avid quail hunters in Mississippi or any other southern state is not known, but we think the number is greater than most wildlife agencies suspect. Agencies could identify avid quail hunters from survey information and interviews with little effort. We believe that avid quail hunters represent a source of valuable information on quail populations (sex and age ratios, population trends), food habits, habitat changes, and other data.

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SUSTAINED HARVEST OF BOBWHITE POPULATIONS

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Abstract: Sport hunting is an important aspect of wildlife management, yet the principles of game harvesting seem not to be particularly well understood or accepted by many in the wildlife profession. This paper examines the two major harvest theories as they apply to the bobwhite. The sustained yield approach is considered conceptually superior to the popular annual surplus theory. Wildlife management admittedly involves practical as well as theoretical considerations; nevertheless, it is important that harvest policy be based on sound scientific principles and guided by clear objectives. To do otherwise puts both the resource and our own professional credibility at risk.

Virtually all professional wildlifers agree that the regulated harvest of certain species is biologically justifiable. In fact, maintenance of huntable populations is often the primary objective of management. Despite this emphasis, relatively little attention is given to the principles of harvesting. Upland game management in particular stresses habitat manipulation rather than population theory, the rationale being that given adequate food and cover, these prolific species can usually take care of themselves. However, as perspectives broaden and resources shrink, wildlife officials are taking a closer look at traditional harvest policies. To do this requires a valid model or conceptual image of how population exploitation works--and therein lies the problem. According to some (Scott 1954, Gross 1969, Wagner 1969, Caughley 1976, McCullough 1979), the wildlife profession has too long adhered to a convenient, but simplistic view of hunting.

This paper examines the two major approaches to game harvesting as they apply to the bobwhite (*Colinus virginianus*). The treatment is purposely general and not intended to provide harvest strategies for specific situations or localities. W. D. Klimstra, David Joyner, Alan Woolf, and Scott Yaich critically read the manuscript and offered helpful suggestions.

ANNUAL SURPLUS VS. SUSTAINED YIELD

The annual surplus concept (Leopold 1933, Errington and Hamerstrom 1935) has traditionally served as the biological justification for hunting. This argument is based on the premise that more individuals are produced each year than can survive. Therefore, it should be possible to remove this "already-doomed" surplus without affecting standing density (Figure 1). Indeed, several studies of upland game species, including the bobwhite (Baumgartner 1944, Vance and Ellis 1972), appear to show that hunting has little if any effect on abundance. However, certain aspects of the annual surplus theory are not supported by other population data (Wagner 1969). For example, the notion that numbers of breeders will be about the same each year regardless of fall population size is not correct. Bobwhite breeding densities are strongly related to previous fall abundance and are no less variable (Roseberry and Klimstra 1983). More important, hunting and nonhunting losses do not appear to be entirely compensatory. I concluded from a long-term bobwhite population study that fall-to-spring mortality rates (and thus breeding densities) were influenced by hunting (Roseberry 1979, 1981; but see also Anderson and Burnham 1981). This assertion does not imply that hunting is detrimental to quail as a species. On the contrary, given their naturally high rate of population turnover, bobwhites are quite resilient to hunting losses. The point here is not that the annual surplus concept is entirely wrong, just that it is incomplete. It says nothing about the size of the harvestable surplus, or its relation to population density or rate of harvest.

In the opinion of many, a more tenable basis for game harvesting is the sustained yield approach. This model of exploitation, pioneered in fisheries management, is based on the interactions of density, production, and rate of increase. According to this view, density-dependent birth and/or death rates (Figure 2a) result in the familiar S-shaped growth curve (Figure 2b), which shows generally how a population would increase if a few individuals were placed into a suitable but empty habitat.

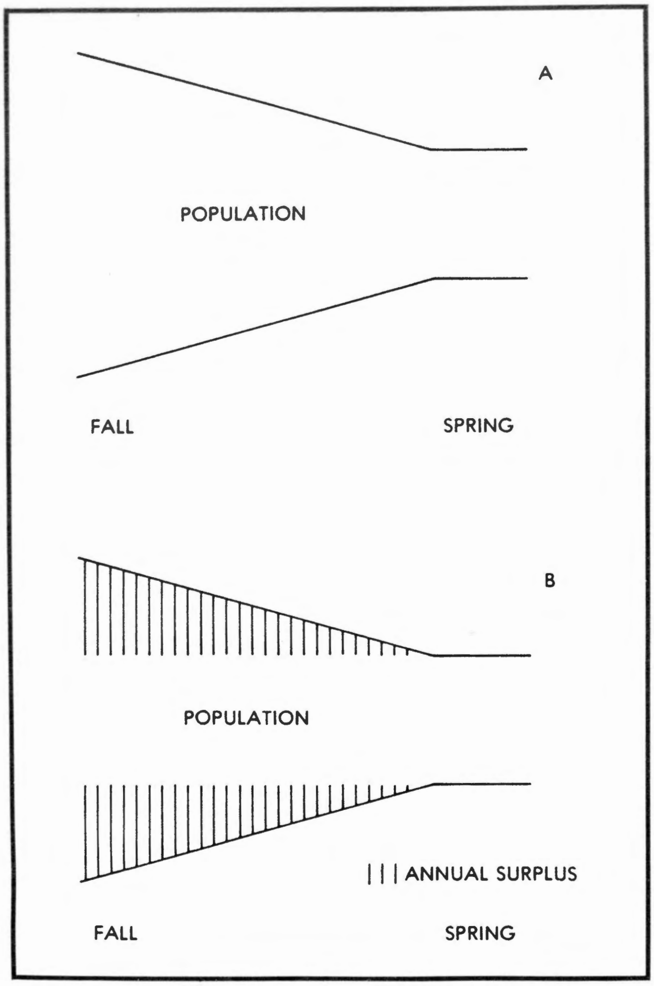

Fig. 1. Traditional view of an "annual surplus".

Growth is initially slow, but accelerates much like compound interest as the breeding stock expands. As numbers approach carrying capacity, the density-dependent birth and death rates begin to converge, thereby slowing and finally halting growth. At this point, the population is said to be at its equilibrium level (K), and though numbers may continue to fluctuate, there can be no further permanent increase unless living conditions improve. The number of new individuals added to the population each year represents net production, or the excess of births over deaths. If this annual growth increment is plotted against numbers already present, a characteristic dome-shaped curve results (Figure 2c), showing production lowest at both population extremes and highest at some intermediate density corresponding to the steep part of the growth curve.

Obviously, real populations are not as neat as diagrammatic charts. There is always a certain amount of variation, random or otherwise. And density dependence refers to general tendencies, not precise, automatic annual adjustments. Nevertheless, population behavior over time often conforms surprisingly well to these textbook generalities, whether the population is mealworms or white-tailed deer. Furthermore, a knowledge of the principles governing population behavior is necessary before specific performance can be interpreted. Be that as it may, some may still be wondering what all this has to do with harvesting game.

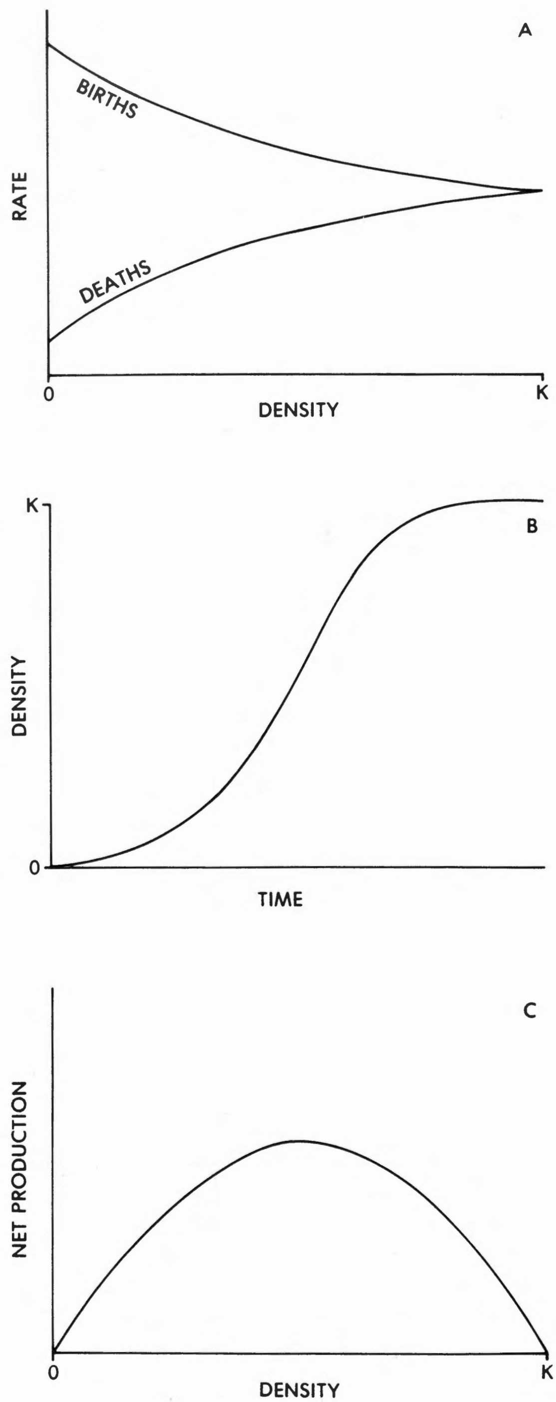

Fig. 2. Interactions of population density, production, and growth.

For one thing, it would seem that a population at carrying capacity would have little if any harvestable surplus. At K, births and deaths are necessarily balanced and the average rate of increase is zero. Excess annual production is characteristic only of populations that are below their maximum density; in other words, those which would normally be increasing. This is the basis for sustained yield harvesting. By maintaining breeding densities at a more productive level below K, we can in effect induce the population to produce a harvestable surplus year after year (what would otherwise be its annual growth increment). The amount that can be taken annually from a population without causing further decline is called the sustained yield (SY) and corresponds to the net production at that level. Thus, populations of game animals do not have a single harvestable surplus; rather, the allowable harvest depends on where density is in relation to carrying capacity. Yields can, therefore, be manipulated by harvesting to maintain population density at a particular level (Figure 3). Generally, a harvest that holds density in the steep part of the growth curve will produce the maximum sustained yield (MSY). Permanently increasing the number removed annually from a population already producing MSY would ultimately extirpate it. Increasing just the rate of harvest though, would simply depress density to the point where adjustments in reproduction and mortality could again accommodate the increased losses due to hunting. When this occurred, the population would stabilize at a new, lower level (Figure 4).

Computer studies indicate that the MSY harvest rate for one southern Illinois quail population might be as high as 55 percent of prehunt densities (Roseberry 1979). This simulated annual harvest maintained average spring and fall populations at about 50 and 70 percent of their respective nonhunted levels. Theoretically, the sustained yield from any particular density should approximate the expected net production. In the case of these simulations, however, sustained yields were considerably greater than this, mainly because the model (and presumably the real population on which it was based) achieved most of its compensation to exploitation within the same year as it occurred.

Bobwhites are able to absorb as much hunting as they do because (1) the impact of fall shooting on breeding densities is numerically less than the actual number of birds removed, and (2) the loss of potential breeders that does occur is partially compensated by density-dependent recruitment the following summer. As noted earlier, the relationship between hunting and nonhunting mortality does not appear to be entirely compensatory; neither, however, is it entirely additive. For example, unhunted midwestern quail populations normally suffer about 50 percent mortality from fall to spring. Even removing half the fall population by hunting would likely increase this figure to no more than about 70 percent. For one thing, some of the birds shot would have died anyway from natural causes. Thus, the number dying naturally is less in a hunted population simply because they are no longer

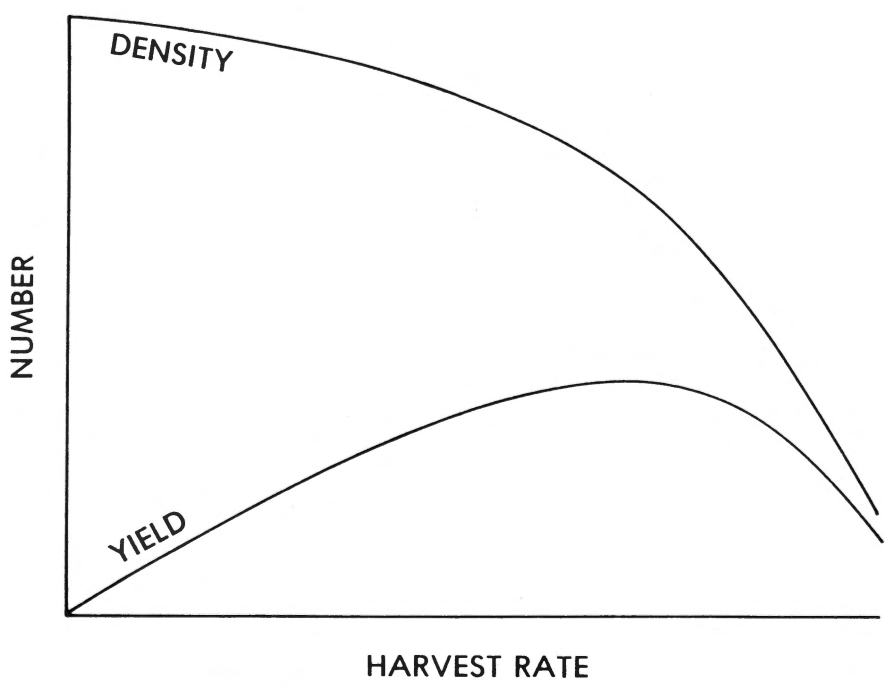

Fig. 3. Relationship of harvest rate to standing density and sustained yield.

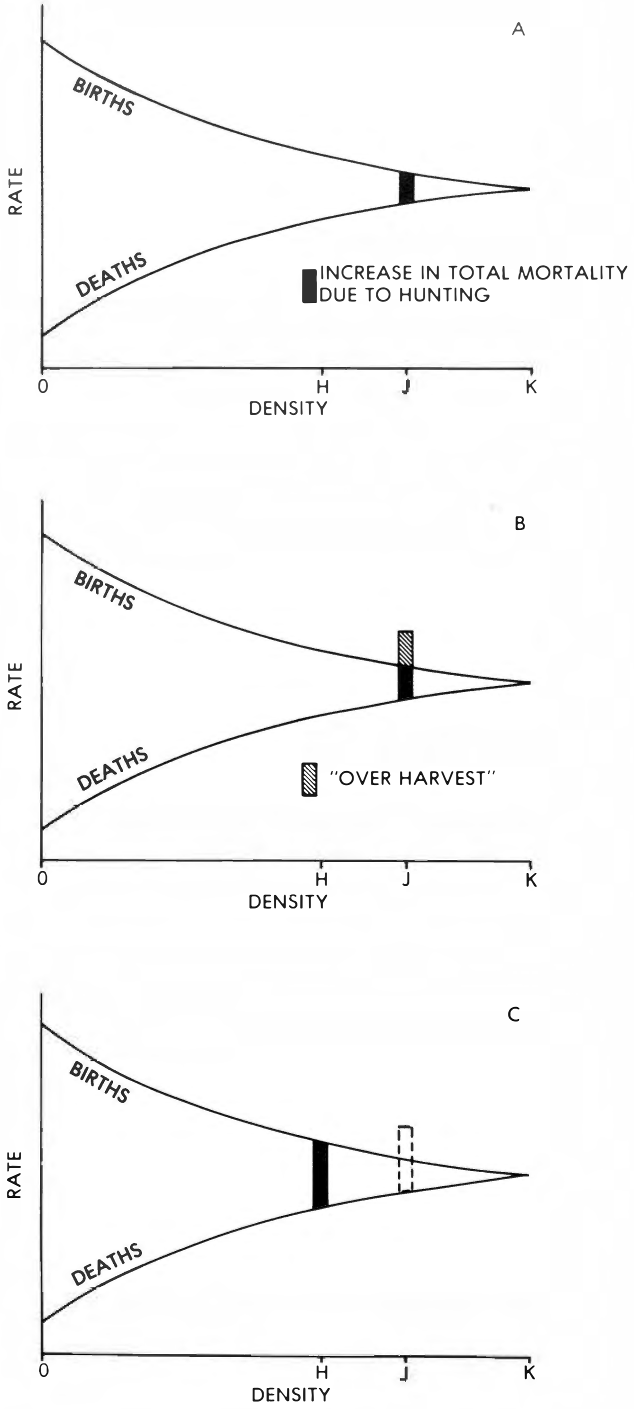

Fig. 4. Diagrammatic population response to increased harvest rate:

A - hunted population stabilized at density _J_;

B - increase in harvest rate temporarily exceeds net production;

C - population declines to and stabilizes at density _H_.

available. In addition, hunting season survivors generally suffer a lower percentage of posthunt mortality because of density dependence. Obviously though, the later in the season that hunting losses occur, the more additive they become to natural mortality. Furthermore, as the percentage of fall-to-spring mortality increases linearly, the percentage of summer gain necessary to offset it increases exponentially (Roseberry 1979). For this reason, the density-dependent nature of bobwhite recruitment plays an important role in the species' ability to absorb hunting. It is particularly significant that the positive response to reduced breeding density is essentially immediate, rather than delayed. This, plus the fact that bobwhite offspring are recruited into the huntable population their first autumn, permits relatively high prehunt densities to be maintained even in heavily hunted situations.

SOME IMPLICATIONS

We have thus far considered the interactions of harvest, density, and yield as if they occurred in a vacuum. In reality, habitat conditions dictate the upper limits of abundance on both hunted and nonhunted areas, and short-term fluctuations are influenced by weather and possibly even cycles (Roseberry and Klimstra 1983). I discussed in a previous paper the harvesting of bobwhites in a fluctuating environment (Roseberry 1979). There are additional reasons why a strictly sustained yield approach is perhaps not as appropriate for quail or other upland game species as it is for big game. For one thing, precise harvesting is difficult except on controlled shooting areas, and hunting pressure itself may vary inversely with game abundance. Certainly, quail management cannot be based solely on theoretical considerations; excellent results are sometimes achieved using a purely pragmatic, common sense approach. Nevertheless, officials must at least be cognizant of the basic principles underlying population dynamics and harvesting. To completely ignore theory in favor of intuition and tradition can lead to some very practical problems (Gross 1972, Caughley 1977, McCullough 1979). The remainder of this paper offers some examples.

A commonly expressed management goal is to maintain target populations at their highest possible level, ostensibly to provide maximum recreational opportunities. Actually, however, these goals are not congruent. Achieving maximum sustained yields requires that spring densities be held well below carrying capacity. Therefore, managers might wish to harvest at a somewhat lower rate if nonconsumptive use of the resource is also a consideration. Of course, improving habitat conditions would benefit both types of users.

Upland game biologists traditionally consider high young:adult ratios indicative of thriving, productive populations. Owing to density-dependent reproduction, however, such ratios are often associated with relatively low breeding densities and are not necessarily characteristic of high autumn populations (Roseberry 1974). Consistently extreme young:adult ratios may be symptomatic of chronically low breeding densities, possibly due to overshooting.

Another problem involves interpretation of population status. Stable numbers are generally considered evidence that management is successful and/or that hunting is having "no effect" on abundance. In reality though, most populations will ultimately stabilize at almost any level under a relatively constant harvest, and this density and associated yield may or may not be consistent with management objectives.

There is also the question of what constitutes a "safe" harvest. Early recommendations ranged from about 30 to 55 percent of prehunt densities (Errington and Hamerstrom 1936, Baumgartner 1944, Hickey 1955). Later, Vance and Ellis (1972) suggested that a 70 percent annual take might not be excessive, whereas Rosene (1969) cautioned that winter losses from all causes should not exceed 45 percent. In my opinion, this lack of consensus reflects an inadequacy of the annual surplus model, namely that its only criterion for judging a particular harvest regime is a supposed absence of population reduction. The common analogy that hunters must take only the "interest" and not touch the "principal" stems from a misconception that the harvestable surplus is a static figure, i.e., that it represents a fixed proportion of each population. In reality, even moderate hunting probably affects the "principal" or breeding stock to some extent. However, under a sustained yield approach, this is not necessarily undesirable. In summary, the question "How much can we hunt a population without 'hurting' it?" is meaningless unless we first establish objectives in terms of densities and yields. Under normal circumstances, it is not a matter of what harvest is "safe," but what is consistent with the overall plan for use of the resource. With game harvesting, as with any management program, agencies should identify and consolidate objectives before implementing policy.

Finally, there is a matter of public image. As stated earlier, most of us support the consumptive recreational use of renewable wildlife resources. Not surprisingly, this support has drawn criticism from anti-hunting groups who publicly question both our professional competence and integrity. As these attacks become more sophisticated (e.g. Favre and Olsen 1982), it is imperative that we maintain credibility. Too often, however, we fail to adequately articulate the scientific rationale for game harvesting, resorting instead to paradoxical cliches such as "Hunting has no effect on healthy wildlife populations, and besides, if we didn't hunt them they would overpopulate and all starve to death." To offer such half-truths and oversimplifications as state-of-the-art wildlife management, or to permit outdoor writers to do so, does a disservice to our profession and, in my opinion, plays right into the hands of the anti-hunting groups.

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AN OVERVIEW OF DISEASE AND PARASITISM IN SOUTHEASTERN BOBWHITE QUAIL[1]

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Abstract: Salient information on diseases and parasites of bobwhite quail (*Colinus virginianus*) in the southeastern United States is summarized. Major diagnostic findings on 146 bobwhites submitted to our regional wildlife disease laboratory from 1972 through 1981 included traumatic injuries, various toxicoses, and avian pox. Traumatic injuries were diagnosed frequently throughout the 10-year period, whereas toxicologic problems occurred sporadically. Avian pox emerged in outbreak proportions in the region in 1978 and thereafter has been prevalent in localized areas. Prompted by severe aflatoxin contamination in southeastern corn crops in 1977, studies on aflatoxicosis in bobwhites indicated that risks to wild bobwhite populations were minimal. Serologic, pathologic, and virus isolation studies disclosed infections of quail bronchitis virus and TR-59 adenovirus in bobwhites in northcentral Florida. Extensive studies have revealed only infrequent minor lesions associated with ectoparasites and endoparasites, and it was concluded that parasitism is not an important mortality factor in wild bobwhites. Two diseases encountered in pen-raised bobwhites, avian pox and histomoniasis (blackhead disease), clearly have potential to produce problems in wild bobwhites and wild turkey.

At the First National Bobwhite Quail Symposium in 1972, Kellogg and Doster presented a comprehensive review of diseases and parasites reported from bobwhites. These authors listed 21 infectious agents and 101 parasites that had been reported in 163 published articles. As was noted, most of the information dealt with pen-raised bobwhites, experimental infections, or general reviews of diseases and was relatively limited with regard to specific or detailed information on diseases and parasites of wild bobwhites. Despite these limitations, this review and a companion review (Kellogg and Calpin 1971) still remain entirely adequate as diagnostic or research checklists.

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Thus, the purpose of the present article is not to provide an updated checklist but rather to provide a synopsis of the most significant or potentially significant diseases in wild bobwhites in the Southeast and to identify those agents which apparently are only rarely the cause of morbidity or mortality in wild bobwhites. Also included is an evaluation of major disease problems in pen-raised bobwhites and an estimate of the risk from these diseases to wild bobwhites where large numbers of pen-raised bobwhites are released into the wild.

METHODS

Information discussed herein originated from three major sources as follows: (1) clinical case records of bobwhites submitted to our regional wildlife disease laboratory (SCWDS) between 1972 and 1981, (2) interim or preliminary information from research projects conducted by SCWDS in collaboration with Tall Timbers Research Station, and (3) published reports.

Clinical case data were compiled from 93 case accessions totaling 127 wild bobwhites and from nine accessions totaling 20 known pen-raised bobwhites. Data on diseases or parasites in these clinical case accessions generally were limited to those necessary for diagnostic efforts.

Where applicable, data from SCWDS research projects in various stages of completion also were included. These data, cited as SCWDS unpublished research data, should necessarily be considered preliminary findings.

Since the authors' experiences with diseases and parasites of bobwhites have generally been limited to the Southeast, the published data included here have also been restricted to the Southeast. Disease agents often have entirely different epizootiologic patterns or differ in significance in various geographic regions. Extrapolation of findings from outside the Southeast could lead to erroneous conclusions.

RESULTS AND DISCUSSION

Clinical Case Data

Diagnostic findings on 127 wild bobwhites submitted to SCWDS between 1972 and 1981 are presented in Table 1. At least six of the 12 fundamental causes of wildlife morbidity and mortality (Hayes and Prestwood 1969) were represented in these cases. Trauma and viral diseases accounted for 70 percent of the primary diagnostic findings. Toxicoses, bacterial infections, mycotic infections, parasitism, and unclassified miscellaneous findings comprised the remainder.

Although providing insight on factors responsible for annual mortality in bobwhites, these data should not be considered an accurate representation of the fates of individuals in wild bobwhite populations. For example, all but one of the large number of avian pox cases occurred during and subsequent to an outbreak of pox (Davidson et al. 1980a, Davidson et al. 1982). The increased awareness of disease problems in bobwhites as a result of the avian pox outbreak stimulated the rate of all clinical case accessions (four/year prior to the outbreak; 29/year during and afterwards) beyond that attributable to avian pox. Available information suggests that the actual significance of avian pox may have been underestimated prior to the outbreak and overestimated following the outbreak.

Although well represented in these data, traumatic injuries probably account for a higher proportion of annual losses than the data suggest. For example, it is illogical to assume higher losses to crippling from sport hunting (approximately one bird lost to four retrieved-Kellogg and Doster 1971, Doster et al. 1982) than from predation. Most bobwhites succumbing to predators are immediately eaten and obviously would not be accounted for in diagnostic data. Similarly, bobwhites weakened by disease are exceedingly vulnerable to predation and theoretically would also be underrepresented.

Table 1. Primary and secondary diagnostic findings in 127 wild bobwhites submitted to SCWDS for diagnostic purposes between 1972 and 1981.[a]

Category/Agent	Primary Factor		Secondary[b] Factor	
Trauma				
Gunshot	10		24	
Impact	9		0	
Predation	4		0	
Penetrating wounds	3		0	
Undertermined	12		0	
Total	38	(30%)	24	(19%)
Toxicoses				
Azodrin[R]	4		0	
Aflatoxicosis	1		0	
Unconfirmed	9		0	
Total	14	(11%)	0	
Viral Infections				
Avian pox	51		5	
Total	51	(40%)	5	(4%)
Bacterial Infections				
Bumblefoot (*Bacillus* sp.)	1		0	
Undetermined	0		4	
Total	1	(1%)	4	(3%)
Mycotic Infections				
Aspergillosis	1		0	
Airsaculitis (*Mucor* sp.)	1		0	
Undetermined	1		1	
Total	3	(2%)	1	(1%)
Parasitic Infections				
Toxoplasmosis	1		0	
Cyrnea colini, *Cheilospirura spinosa*, *Dispharynx nasuta*	2		0	
Total	3	(2%)	0	
Miscellaneous				
Intrathoracic Hemorrhage	2		0	
Crop Impaction	1		0	
Kidney Dysfunction	1		0	
Malnutrition, Dehydration	1		1	
Degenerative Myopathy	0		1	
Abdominal hernia	0		1	
Normal	9		0	
Undetermined	3		0	
Total	17	(13%)	3	(2%)
Grand Total	127	(100%)	37	(29%)

[a]In some cases diagnostic findings were multiple and were rated as primary or secondary factors.
[b]All secondary gunshot entries involved hunter-killed birds that were submitted due to external lesions or abnormal behavior; all secondary avian pox entries involved detection of pox lesions incidental to other diagnostic findings; all secondary entries under bacterial, mycotic, or miscellaneous headings were a direct result of prior traumatic injuries.

Clinical case data on toxicoses in bobwhites reveal sporadic occurrence and a high percentage of unconfirmed cases. Generally, poisoning is one of the first causes considered when sick or dead wildlife are encountered, but as noted by Hayes and Prestwood (1969), it is not nearly as frequent as commonly thought. Furthermore, toxicoses are difficult to confirm especially when few specimens are found and case histories provide no clues on suspected poisons.

In addition to the 127 wild bobwhites in Table 1, nine case accessions totaling 20 pen-raised bobwhites were examined. The diagnoses for these accessions were gunshot--one accession; malnutrition--one accession; stress (probably suffocation and heat prostration)--one accession; avian pox--three accessions; blackhead--two accessions; and pneumonia/sinusitis--one accession. In addition, one of the blackhead cases had a secondary factor of crop capillariasis. With the exception of the diagnoses of gunshot and avian pox, the diseases and conditions observed in pen-raised bobwhites are most often considered "diseases of confinement." They were not encountered in wild bobwhites.

Avian Pox

Information on avian pox in wild southeastern bobwhites has been summarized in detail (Davidson et al. 1980a, 1982). Briefly, avian pox is entrenched in wild bobwhites in the Southeast and in 1978 occurred in outbreak proportions. Following the outbreak, pox has been detected annually and has been an important disease of bobwhites in local areas. Avian pox is the only infectious disease (Table 2) of wild bobwhites that has been directly associated with significant annual mortality. Gross lesions of pox infection typically are proliferative lesions on epithelial tissues of the skin, nares, and oral cavity. Lesions can cause fatalities by impairing vision, respiration, or feeding, or they can result in death indirectly by increasing vulnerability to predation.

Table 2. Infectious agents encountered in wild bobwhites in the Southeast (compiled from Davidson et al. 1980, Wiseman 1979, King et al. 1981, SCWDS, unpubl. data).

Viral agents[a]	Quail bronchitis virus (QBV), TR-59 adenovirus, avian pox virus
Bacterial agents	*Bacillus* sp.
Mycotic agents	*Aspergillus* sp., *Mucor* sp., *Candida albicans*

[a]Serologic tests for Newcastle disease virus and isolation attempts for influenza A viruses were uniformly negative.

Aflatoxicosis

A three-year study was completed on Tall Timbers Research Station (1) to determine whether mycotoxins occur in grain crops (corn primarily) used by wild bobwhites for feed, (2) to determine whether these mycotoxins (aflatoxins) were ingested by bobwhites, and (3) to evaluate whether ingested levels had caused any pathologic changes in the animal. Aflatoxins were cyclically present in these crops, were ingested by bobwhites, and on occasion did produce slight to moderate pathologic processes. A range of levels of aflatoxins found to normally occur in corn (0.5, 1.0, 2.0, and 4.0 ppm) was fed to fourth generation-removed pen-raised bobwhites, and physiochemical and pathophysiologic parameters were measured. No significant abnormalities were noted until the level of aflatoxin in the feed equalled or exceeded the highest level found to naturally occur in field corn. Analysis of tissues from birds also yielded active aflatoxins in various forms. The abnormalities noted in physiochemical parameters loosely paralleled those documented in other gallinaceous birds (Peckham 1978). In the experimental birds, egg production also was significantly affected. The relationship between aflatoxicosis and protein synthesis inhibition, especially in the globulin components, deserves further study since immunosuppression is a consistent effect of aflatoxicosis in commercial poultry. This study suggests that aflatoxicosis alone probably is not a regular or major mortality factor in wild bobwhites (SCWDS, unpubl. data).

Avian Adenoviruses

Quail bronchitis, caused by an avian adenovirus (quail bronchitus virus-QBV), is an acute respiratory disease characterized by rapid spread and high mortality (DuBose 1978). Clinical disease has been described only in young (< 8 week old) pen-raised bobwhites, and experimental transmission studies most often fail to reproduce clinical disease (DuBose 1978). Recent studies suggest that an additional viral agent (avian adenovirus-associated virus--A-AV) may be required for the production of clinical disease (Bagshaw et al. 1980).

During studies on diseases and parasites of bobwhites at Tall Timbers Research Station in February 1975, intranuclear inclusion bodies were detected in the livers of many bobwhites. Since that time, a series of studies has been conducted to identify the agent (presumed to be a virus) responsible for these inclusion bodies. Serologic tests and virus isolation attempts on bobwhites from Tall Timbers and two nearby bobwhite populations in Georgia revealed infections of avian adenoviruses (Table 2). Two related viruses, QBV and TR-59 adenovirus, were isolated (Wiseman 1979, King et al. 1981). Either one or both viruses are considered to be the etiologic agent(s) of the inclusion bodies (King et al. 1981).

Histopathologic studies also have revealed small, inconspicuous lesions (microfocal necrosis, lymphocytic infiltration, microgranulomas) in the livers of bobwhites. These lesions, many of which are not visible grossly but are detected histologically, are associated ($P < 0.05$) with the presence of viral inclusion bodies (SCWDS, unpubl. data). Juvenile birds had higher ($P < 0.01$) prevalences of inclusion bodies than adults (46 percent vs 27 percent) (SCWDS, unpubl. data), but adult birds more frequently had antibodies (King et al. 1981). Differences in the prevalence of inclusion bodies or antibodies were not noted between sexes ($P > 0.05$). Bobwhites sampled annually in February from 1975 through 1980 on each of two 200 ha study areas on Tall Timbers Research Station had identical trends in the prevalence of intranuclear inclusion bodies. The trend comprised a steady rise in prevalence (except for a slight decline in 1978) from $\leq$ 10 percent in 1975 to a peak (45 and 60 percent) in 1979, then an abrupt decline in 1980 ($\leq$ 9 percent).

These findings indicate that wild bobwhites in at least some locales are naturally infected with QBV and TR-59 adenoviruses; however, clinical disease in wild bobwhites has not been attributed to these infections. Further, the significance of intranuclear inclusion bodies in hepatocytes is unknown (i.e., do they represent active infections, latent viral particles, an immune host, etc.). The potential of these viruses to produce clinical disease in wild bobwhites and possibly influence bobwhite population levels deserves clarification.

Parasitism

Since 1963, the SCWDS has conducted various research projects on parasitism in bobwhites on an annual basis, and most of these studies have been reported elsewhere (Kellogg and Prestwood 1968; Kellogg and Reid 1970; Palermo and Doster 1970; Davidson et al. 1978, 1980b; Doster et al. 1980). In addition to the above reports, SCWDS has monitored parasitism in bobwhites (N=600) at known densities on two study areas on Tall Timbers Research Station for 12 consecutive years (1971-1982) as part of a long-term study of bobwhite population dynamics. Species of parasites found in these studies and an assessment of their pathogenic potentials are summarized in Tables 3-5.

An overview of these data reveals that parasitism in bobwhites is almost invariably subclinical and that parasites which occur frequently in wild bobwhites have limited pathogenicity. These studies suggest that parasitism is not an important regulator of bobwhite populations.

Disease Risks from Pen-raised Bobwhites

The practice of releasing pen-raised bobwhites for sporting purposes (i.e., hunting, dog training, field trials) is common in many areas and often is controversial because of concern for disease risks and other reasons. We have had numerous occasions to study the potential disease problems that could arise from this practice, and the following is a synopsis of our view on the disease risks from this practice. We realize that releases of pen-raised bobwhites often are mandated by the objectives of some landowners, particularly commercial shooting preserves. Our position is that it is in the best interest of the landowner from an economic standpoint and the wildlife resources from a biologic standpoint that only healthy bobwhites are used.

Significant diseases and parasites of pen-raised bobwhites are tabulated in Table 6. Also included in the table are our assessments of the risk each agent poses to wild bobwhites or other wild game birds. Most of these diseases or parasites appear to reach problem levels only under pen-raised conditions and can be categorized as "diseases of confinement." Only two diseases, avian pox and histomoniasis (blackhead disease), are presently considered to have substantial risks to wild game birds. A high risk rating was applied to these two diseases because (1) they produce high morbidity and mortality rates, (2) they are capable of persisting under field conditions, (3) they have been detected under natural conditions, and (4) their occurrence in the wild occasionally has been associated with releases of bobwhites. The cecal worm, Heterakis gallinarum, also is listed as a high risk since it is the vector for histomoniasis.

We have observed instances where both avian pox and blackhead disease have been present in pen-raised bobwhites destined for release, and we also have found both diseases in clinical case accessions of pen-raised bobwhites from the field following release. The potential for bobwhites to serve as disseminators of blackhead disease among wild turkeys (Meleagris gallopavo) has been evaluated by various researchers (Davidson et al. 1978, Kellogg and Reid 1970, Lund and Chute 1971). Clearly pen-raised bobwhites pose a greater risk as blackhead carriers than wild bobwhites

Table 3. Protozoan parasites found in wild bobwhites from the Southeast (compiled from checklist by Kellogg and Doster 1972).

Organism/Group	Location	Pathogenicity
Coccidia		
Eimeria spp.	Intestine	None reported
Eimeria dispersa	Intestine	None reported
Blood Parasites		
Haemoproteus sp.	Erythrocytes	None reported
Plasmodium spp.	Erythrocytes	None reported
Flagellates		
Trichomonas spp.	Ceca	None reported
Histomonas meleagridis[a]	Ceca, Liver	Moderately severe--30-70% mortality

[a]Reports in wild bobwhites are extremely infrequent; rather frequent in pen-raised bobwhites.

Table 4. Helminth parasites found in 937 wild bobwhites from the Southeast (compiled from Davidson et al. 1980b, Kellogg and Prestwood 1968, Palermo and Doster 1970, and SCWDS, unpubl. data).[a]

Group/Location	Species	Pathogenicity
Trematodes		
Intestine	Brachylaima sp.	None reported
Liver	Brachylecithum nanum	None reported
Cestodes		
Intestine	Hymenolepis sp., Raillietina cesticillus, R. colinia, Rhabdometra odiosa	Mild-occasional intestinal obstruction
Acanthocephalans		
Intestine	Mediorhynchus papillosis	None reported
Nematodes		
Eye	Oxyspirura matogrosensis	None reported
Air sacs	Aproctella stoddardi	Mild inflammation
Crop	Capillaria contorta	None reported
Esophagus	Gongylonema ingluvicola	None reported
Proventriculus	Cyrnea colini, Dispharynx nasuta, Tetrameres pattersoni	Mild inflammation
Gizzard	Cheilospirura spinosa	Mild inflammation
Intestine	Ascaridia lineata, Capillaria sp., Strongyloides avium,	None reported
Ceca	Heterakis bonasae, H. gallinarum, Subulura sp., S. brumpti, Trichostrongylus tenuis	None reported

[a]SCWDS unpublished data include bobwhites from the following locations: 500-Tall Timbers Research Station, Leon Co., FL; 62-Corbett Wildlife Management Area, Palm Beach Co., FL; 44-Catfish Point. Bolivar Co., MS; 25-Quantico Marine Corps Base Prince William/Stafford counties, VA; 20-Pulaski, Prairie, and Lonoke counties, AR; and 10-Charlotte Co., FL.

Table 5. Arthropod parasites collected from 481 wild bobwhites from the Southeast (adapted from Doster et al. 1980)[a]

Ticks	Amblyomma americanum, A. maculatum, Haemaphysalis chordeilis, H. leporispalustris, Ixodes minor
Chiggers	Eutrombicula alfreddugesi, Neoschoengastia americana, Neotrombicula whartoni
Nasal mites	Boydaia colini, Colinoptes cubanensis
Feather mites	Pterolichus sp., Megninia sp.
Shaft mites	Coliniphilus wilsoni, Dermoglyphus sp., Apionacarus wilsoni
Skin mites	Microlichus sp., Rivoltasia sp.
Lice	Menacanthus pricei, Colinicola numidiana, Gonoides ortygis, Oxylipeurus clavatus

[a]Significant lesions were not associated with any species.

Table 6. Important infectious agents and parasites often encountered in pen-raised bobwhites and their significance to wild bobwhites and other game birds.[a]

Etiologic Agent	Disease Produced	Risks to Wild Bobwhites
Infectious Agents		
Quail bronchitis virus (QBV)	Quail bronchitis	Unknown--occurs naturally in wild bobwhites in some areas
Avian pox virus	Avian pox	High risk--can initiate or exacerbate the occurrence of pox in wild bobwhites and possibly other game birds
Clostridium colini	Ulcerative enteritis	Apparently low risk--never reported from wild bobwhites
Aspergillus fumigatus	Aspergillosis	Low risk--organism is ubiquitous
Candida albicans	Crop mycosis	Low risk--organism is ubiquitous
Parasites		
Histomonas meleagridis	Histomoniasis (blackhead disease)	High risk--pathogenic to wild bobwhites and wild turkeys
Capillaria contorta	Crop capillariasis	Low risk--extremely rare in wild birds
Dispharynx nasuta	Dispharynxosis	Low risk--parasite is ubiquitous
Heterakis gallinarum	None (blackhead vector)	High risk--important as vector for blackhead disease

[a]Information in this table is derived from the authors' experiences with bobwhite diseases, and conclusions are based on their assessments of disease risks.

(Davidson et al. 1978). Initiation or exacerbation of avian pox problems by the release of pen-raised bobwhites has not been definitely proved, but we have noted situations where this was strongly suspected.

The best precaution for minimizing risks from these diseases is to examine by necropsy a sample of bobwhites prior to release. There are prevention and control measures (basically sanitation and the judicious use of vaccination and medication) available to producers of pen-raised bobwhites that will help ensure minimal disease problems. These procedures should be conducted with the supervision of a poultry diagnostic laboratory or other qualified professional.

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AVIAN POX INFECTIONS IN SOUTHEASTERN BOBWHITES: HISTORICAL AND RECENT INFORMATION[1]

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Abstract: Historic and recent information on the occurrence of avian pox, an infectious viral disease, in southeastern bobwhite quail (*Colinus virginianus*) is summarized. An apparent long-term (> 50 year) low-level (< 2 percent) rate of infection occurred prior to an outbreak with a 12-fold increase in prevalence in 1978-1979. Post-outbreak monitoring during the two succeeding years disclosed that the regional prevalence of infection declined to near the pre-outbreak rate. The significance of avian pox as a regional and local mortality factor is discussed.

Avian pox is a viral infection of birds, characterized by discrete proliferative (wart-like) lesions on the skin and/or mucous membranes of the mouth and upper respiratory tract. There are several strains of avian pox viruses, many of which are of varying virulence, but all of which are infective only to birds. Some strains of the virus are host specific and infect only certain species of birds, whereas other strains are less host specific and may infect many species. The virus may be transmitted by several routes, including (1) contact with or ingestion of infectious scabs, (2) inhalation of viral particles in dust, or (3) by blood-feeding arthropods, particularly mosquitoes (Cunningham 1978). Mosquito-borne infection is generally considered to be the most important means of transmission among wild birds, and several species of mosquitoes have been shown to be natural vectors of pox viruses in wild game birds in the Southeast (Akey et al. 1981). Avian pox may occur in two forms. The cutaneous form involves lesions which develop primarily on the unfeathered portions of the skin (legs, feet, eyelids, head) and, unless vision is impaired, is not usually a serious disease. The moist or wet form involves lesions which develop on the mucous membranes of the mouth, nasal passages, and upper respiratory tract and often leads to a serious disease due to impairment of feeding and/or respiration. In birds which survive, avian pox lesions generally regress spontaneously 6 to 12 weeks after infection. Morbidity and mortality rates from pox infection are influenced by a variety of factors and may range from near zero to over 50 percent of a population (Cunningham 1978).

Reports of avian pox in wild bobwhite quail have been infrequent, although this disease has been a sporadic problem in captive bobwhites (Morley 1933, Shillinger and Morley 1937, Poonacha and Wilson 1981). This situation changed abruptly in 1978-1979 in the southeastern United States when an outbreak of avian pox occurred in wild bobwhites (Davidson et al. 1980). This report (1) summarizes published accounts of avian pox in bobwhites prior to the 1978-1979 outbreak, (2) reviews the 1978-1979 outbreak in the Southeast, (3) presents the results of region-wide avian pox surveillance conducted during two years following the 1978-1979 outbreak, (4) evaluates available epizootiologic information, and (5) discusses the implications of avian pox for wild bobwhites in the Southeast.

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of Veterinary Medicine, The University of Georgia, graciously assisted with laboratory support.

METHODS

Information on the occurrence of avian pox in wild bobwhites prior to the 1978-1979 outbreak was obtained by a review of the literature and from unpublished records of the Southeastern Cooperative Wildlife Disease Study (SCWDS). Data on the 1978-1979 outbreak were obtained from the description of the outbreak (Davidson et al. 1980) and were supplemented by additional unpublished records of the SCWDS and by a follow-up questionnaire distributed by Tall Timbers Research Station.

Post-outbreak surveillance was conducted during bobwhite hunting seasons in 1979-1980 and 1980-1981. Requests for assistance with surveillance were channelled through state fish and wildlife agencies in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia and through Tall Timbers Research Station, Tallahassee, Florida. Via this system, hunters were asked to retain and freeze the head, wings, and the unfeathered portion of the legs and feet of bobwhites for examination. Additional data requested were the specific location, county, state, and date of collection. Samples generally were limited to $\leq$ 100 per location. All bobwhites handled during bobwhite management studies by the SCWDS at Tall Timbers Research Station during February 1979, 1980, and 1981 also were examined. Age and sex of birds were determined by plumage characteristics (Stoddard 1931). Pox infection of these samples was determined on the basis of gross lesions and was accompanied by histologic confirmation of questionable lesions.

RESULTS AND DISCUSSION

Pre-outbreak Data

A review of the literature revealed only four published reports of avian pox in wild bobwhites prior to the 1978-1979 outbreak (Table 1). Collectively these reports suggest that avian pox has existed in wild southeastern bobwhite populations at least since the 1920s and probably prior to that time. Such infections typically appeared to be mild and transient with only occasional birds reaching a debilitated condition due to pox infection. The single report by Gallagher (1916) of large scale mortality involved wild-caught birds crowded into cages. The confinement conditions undoubtedly were related to increased transmission and high infection rates. In the 15 years prior to 1978, only a single bobwhite with avian pox had been submitted to the SCWDS diagnostic laboratory.

Outbreak Data

The 1978-1979 outbreak of avian pox was described in detail by Davidson et al. (1980). From July 1978 through March 1979, 26 separate unsolicited clinical case accessions involving 43 wild bobwhites from southeastern Georgia/northcentral Florida were diagnosed as avian pox by the SCWDS. A survey of 2,586 hunter-killed bobwhites from Florida, Georgia, North Carolina, South Carolina, Tennessee, and West Virginia conducted during January and February, 1979, disclosed an overall rate of infection of 12 percent (312 birds). Most (77 percent) of the 312 infected birds had only mild lesions on the legs and feet with the remaining birds (23 percent) having more extensive lesions of the eyes, nares, and oral cavity. The prevalence of infection varied greatly among

Table 1. Reports of the occurrence of avian pox in wild bobwhites prior to an outbreak of pox in 1978-1979.

Source	Date	Location	Circumstances
Gallagher (1916)	1916	Kansas City	Severe disease developed in a group of 400 wild-caught bobwhites imported from Mexico; 85 percent mortality
Stoddard (1931)	1924-1929	"Southeast"	Pox lesions observed on legs and feet of <2 percent of several thousand bobwhites; in some coveys the majority were infected; two cases with lesions on head reported (GA, SC)
Kellogg and Doster (1972)	1972	Baker Co., GA	Single sick bird caught by hand; lesions on legs and around nares[a]
Davidson et al. (1980)	1969-1978	Leon Co., FL	Mild pox lesions observed on legs and feet of less that one percent of over 8,300 bobwhites; no mortality reported

[a]Circumstances from unpublished SCWDS case records.

Table 2. Results of avian pox surveillance in wild bobwhites in the Southeast during three successive hunting seasons, 1978-1979, 1979-1980, 1980-1981.

State/County	Number Infected/Number Examined 1978-79	1979-80	1980-81
Arkansas			
Conway			0/8(0)
Izard			0/25(0)
Logan			0/40(0)
Pope			0/30(0)
Stone			1/115(1)
Yell			2/53(4)
"Southwest AR"			2/74(3)
			5/345(1)
Florida			
Charlotte		5/44(11)	5/104(5)
Citrus	0/18(0)[a]	0/64(0)	0/26(0)
Jefferson	4/114(4)		0/13(0)
Leon	80/902(9)	2/829(<1)	21/925(2)
Osceola	0/3(0)	1/58(2)	
Santa Rosa			2/23(9)
Not Given			0/59(0)
	84/1037(8)	8/995(1)	28/1150(2)
Georgia			
Baker			1/63(2)
Brooks	6/24(25)	10/68(15)	1/53(2)
Bullock		1/7(14)	
Burke		5/50(10)	0/26(0)
Decatur	40/308(13)	9/125(7)	7/57(12)
Dougherty	56/493(11)		10/49(20)
Grady			13/44(30)
Jackson			0/2(0)
Jefferson		3/21(14)	0/1(0)
Lee	0/6(0)		
Mitchell		10/68(15)	
Oglethorpe		0/6(0)	1/14(7)
Putnam			0/9(0)
Screven	13/34(38)	2/13(15)	2/52(4)
Sumpter	0/6(0)		
Thomas	88/413(21)	17/216(8)	19/259(7)
Toombs	8/23(35)		
Truetlan	7/18(39)	2/7(29)	
Washington	1/12(8)		
Wheeler		6/9(67)	0/6(0)
Worth			0/100(0)
	219/1337(16)	65/590(11)	54/735(7)
Louisiana			
Caldwell			0/13(0)
Catahula			0/4(0)
East Carrol			0/6(0)
Ouachita			0/1(0)
Union			1/38(3)
			1/62(2)

Table 2. (Cont.)

State/County	Number Infected/Number Examined 1978-79	1979-80	1980-81
North Carolina			
Bladen	1/21(5)		
Chatham	0/4(0)		
Craven	0/4(0)	1/17(6)	
Cumberland	0/11(0)		
Edgecombe	0/1(0)		
Green/Pitt	1/20(5)		
Halifax	0/2(0)		
Hoke/Moore		0/35(0)	0/5(0)
Harnet		1/20(5)	4/28(14)
Jones	0/8(0)		
Lenoir	5/53(9)		
Montgomery		1/20(5)	
Northhampton	2/32(6)		
Richmond	0/6(0)	3/29(10)	
Robeson	0/15(0)		
Scotland	0/3(0)		0/6(0)
Wake		0/2(0)	
	9/169(5)	6/123(5)	4/50(8)
South Carolina			
Allendale		2/11(18)	
Berkeley		0/20(0)	
Hampton	0/23(0)	0/56(0)	0/98(0)
Marlboro	0/3(0)		
Oconee			0/2(0)
Pickens			0/21(0)
Williamsburg		4/57(7)	0/64(0)
	0/26(0)	6/144(4)	0/185(0)
Tennessee			
Fayette	1/6(17)		
Henderson	0/9(0)		
	1/15(7)		
Virginia			
Accomack		7/39(18)	
Caroline		0/60(0)	0/40(0)
Culpepper		0/12(0)	0/13(0)
Dinwiddie/ Nottoway		0/36(0)	0/68(0)
Essex			0/32(0)
King and Queen		1/28(4)	0/16(0)
King William		0/4(0)	
Madison			0/2(0)
Nelson			0/14(0)
Northumberland		2/26(8)	0/28(0)
Rappahannock		0/33(0)	0/15(0)
Richmond			0/1(0)
Southampton			0/4(0)
Sussex		0/38(0)	
		10/276(4)	0/233(0)
West Virginia			
Mason	0/4(0)		
	0/4(0)		
Southeast Total	313/2588 (12.1)	95/2128 (4.5)	92/2760 (3.3)

[a]Percent infected in parenthesis.

specific locales with the highest detected rate being 39 percent. The 12 percent prevalence was estimated to represent approximately a 12-fold increase in prevalence. Based on clinical case and survey data, morbidity and mortality rates of approximately 2 percent and 1 percent, respectively, were estimated for a 13,000 km^2 area of Georgia and Florida during the interval of January and February 1979. No differences in infection rates were noted among different age or sex categories, and it was concluded that all segments of the population were affected equally.

Post-outbreak Data

The results of region-wide surveillance activities conducted during the hunting seasons of 1979-1980 and 1980-1981 are presented in Table 2 along with similar information from 1978-1979 for comparative purposes. On a region-wide basis, post-outbreak surveillance showed lower overall rates in 1979-1980 (4.5 percent) and 1980-1981 (3.3 percent) than during the outbreak (12.1 percent). Sufficient data were available from nine specific locations in each of the three years for annual comparisons (Table 3). The prevalence of pox on these areas exhibited varying trends, although similar trends were detected on five of the seven areas where infections occurred. The pattern in these cases was a decline in prevalence from 1978-1979 to 1979-1980 followed by a slight increase in prevalence in 1980-1981. One of the remaining areas was highest in 1979-1980, and the other declined in both 1979-1980 and 1980-1981. The annual mean prevalence for data from these nine areas (adjusted for unequal sample sizes) was highest (13.2 percent) in 1978-1979 and approximately equal in 1979-1980 (5.6 percent) and 1980-1981 (4.8 percent). Collectively these data indicate that during the two years following the outbreak, the prevalence of pox generally declined to approximately one-third the rate during the outbreak although marked local differences in prevalence existed as were noted during the outbreak (Davidson et al. 1980).

Fewer accessions of clinically affected bobwhites were received by the SCWDS in the two years following the outbreak. During 1979-1980, three accessions involving four bobwhites were diagnosed as pox infections, and in 1980-1981 there were 12 accessions involving 15 bobwhites. These data also indicate a decline in the occurrence of clinical pox infections especially considering that general awareness of the disease was much greater than in 1978-1979.

Related Epizootiologic Data

A questionnaire distributed in November 1979, among individuals cooperating in surveillance activities provided one particularly interesting fact. In response to the question of whether they had observed avian pox in bobwhites prior to 1978, two respondents, one in Brooks County, Georgia, and one in Colquitt County, Georgia, indicated that they had observed infected bobwhites in 1977. These reports suggest that avian pox may have begun to increase in 1977, a year before the outbreak was generally recognized.

A widespread and rather severe problem due to avian pox occurred during the summer and fall of 1978 among pen-raised bobwhite operations in the Southeast, including Florida, Georgia, South Carolina, and North Carolina. Avian pox infections also had been noted in a breeder flock of bobwhites in Kentucky during the fall of 1977 (Poonacha and Wilson 1981). These occurrences raised the question of whether release of pen-raised bobwhites might be related to the pox situation in wild bobwhites. Review of available information did not provide evidence that the region-wide increase in avian pox infections in 1978 was related directly to the avian pox problem that occurred simultaneously in captive bobwhites. The occurrence of avian pox in increased levels at locations where pen-raised birds were not present, such as Tall Timbers Research Station, indicates that the outbreak probably arose from the naturally-occurring low level of pox in wild

Table 3. Comparison of the prevalence of avian pox in bobwhites from nine specific locations during three successive hunting seasons.

Location No.	County/State	Number Infected/Number Examined 1978-1979	1979-1980	1980-1981
1	Leon, FL	14/90(16)[a]	0/24(0)	3/105(3)
2	Leon, FL	47/324(15)	2/450(<1)	10/508(2)
3	Leon, FL	4/320(1)	0/322(0)	8/312(3)
4	Citrus, FL	0/18(0)	0/64(0)	0/26(0)
5	Thomas, GA	15/58(31)	1/46(2)	5/72(7)
6	Thomas,, GA	10/219(5)	15/60(25)	14/115(12)
7	Decatur, GA	40/308(13)	9/125(7)	7/57(12)
8	Screven, GA	13/34(38)	2/13(15)	2/52(4)
9	Hampton, SC	0/23(0)	0/56(0)	0/98(0)
	Total	146/1394(10.5)	29/1160(2.5)	49/1345(3.6)
	Annual mean prevalence[b]	13.2%	5.6%	4.8%

[a]Percent infected in parenthesis
[b]Adjusted for unequal sample sizes

bobwhites. Conversely, there was circumstantial evidence that in some specific locations release of pen-raised bobwhites contributed to and intensified pox problems. For example, the high prevalence at location 6 (Table 3) in 1979-1980 apparently was related to release of pen-raised bobwhites. At another location, approximately 1,000 bobwhites were known to have been released while over 50 percent were experiencing clinical disease due to avian pox. Such cases clearly could contribute to the perpetuation of pox infections on these localized areas.

An additional point of interest with regard to the increased occurrence of avian pox in bobwhites was the host range of the virus and its ability to produce disease in other species such as domestic poultry and wild turkeys (Meleagris gallopavo). A series of laboratory tests and experimental infections were conducted in collaboration with the Poultry Disease Research Center, College of Veterinary Medicine, The University of Georgia (Dr. Pedro Villegas and Dr. Mark Dekich, unpubl. data). These studies provided the following basic findings: (1) viral neutralization and vaccination-challenge trials indicated that bobwhite isolates were immunologically different from the fowl pox strain of avian pox viruses; (2) isolates of pox virus from bobwhite field cases (wild and pen-raised) produced transient lesions in domestic chickens and turkeys but were not infective to coturnix quail (Coturnix coturnix); and (3) commercial fowl pox vaccines provided protection against challenge with bobwhite isolates, but bobwhite isolates did not protect against challenge with the fowl pox strain of avian pox virus.

SUMMARY AND CONCLUSIONS

Avian pox infections have occurred naturally in wild bobwhites in the Southeast for a long time (> 50 years) at a low prevalence (< 2 percent). For reasons that are not known, avian pox infections increased approximately 12-fold in the southwest Georgia/northcentral Florida region in 1978-1979. Mortality due to pox infection in this region was estimated to be approximately one percent during January and February 1979 but probably was considerably more during the period of July-December 1978, when environmental conditions were more favorable for arthropod vectors, primarily mosquitoes. A similar seasonal occurrence of avian pox and mosquito transmission of pox viruses have been demonstrated in wild turkeys in Florida (Akey et al. 1981, D. L. Forrester, pers.comm. 1981). During the two years following the outbreak, the regional prevalence of infection declined to near the pre-outbreak level. On a local basis, the prevalence of infection can vary markedly, and mortality in specific locales can be much greater or much lower than in the region as a whole. Although releases of infected pen-raised bobwhites were not known to initiate the 1978-1979 outbreak, use of pen-raised birds apparently did contribute to pox problems on local areas. Where releases are necessary, birds vaccinated with commercial fowl pox vaccines eight to ten weeks prior to arrival on release properties provide minimal risks. The trend that avian pox infections in southeastern bobwhites will take in the future is entirely speculative; however, historical accounts and data obtained subsequent to the outbreak provide considerable indications that the disease will return to the relatively quiescent status maintained prior to 1978.

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MODERN PESTICIDES AND BOBWHITE POPULATIONS

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Abstract: Bobwhite (*Colinus virginianus*) are frequently used as test animals for wildlife tests of pesticides. The organophosphate and carbamate pesticides that have replaced the organochlorines have many desirable properties, but they span a wide range of acute toxicities and some of them affect survival, reproduction, food consumption, behavior, and nervous system enzymes in laboratory tests. Applying these laboratory findings to the field requires assumptions about the severity of exposure in the field. Direct field measurements show that birds may be exposed to significant amounts of these pesticides or even more toxic degradation products under some conditions. Adverse population effects may also result from depression of insect populations during the seasons when bobwhites rely on insects for food.

The possible reduction of wildlife populations by pesticides has been a concern of wildlife biologists since the organic insecticide era began in the 1940's. As early as 1945, tests of DDT's effect on wildlife were being conducted both in the field and laboratory (Coburn and Treichler 1946, Cottam and Higgins 1946, Nelson and Surber 1947). It appears that a 1948 test of parathion was the first wildlife test of an organophosphate (OP) insecticide (Linduska and Springer 1951). Bobwhites were used in these early controlled investigations because they are an important game species and are relatively easily maintained in captivity. The bobwhite is still frequently used as a representative wildlife species for tests of many OP and carbamate (CA) pesticides that are replacing the original organochlorine pesticides like DDT.

Organochlorine insecticides are relatively persistent in the environment. This was initially thought to be a desirable property of these chemicals, but the ecological consequences of the buildup of these chemicals in natural systems have been a major factor in the replacement of the organochlorine insecticides with OP and CA insecticides. These replacement insecticides are degraded relatively rapidly by both chemical and biological processes. They do not appear to be concentrated in higher levels of food chains and their acute effects on birds and mammals seem to be reversible after exposure ceases. Despite these favorable properties, many OP and CA insecticides are extremely toxic and have caused problems. In this paper, I will attempt to provide a practical perspective on the potential effects of these chemicals on bobwhite populations. Many of the questions about effects on bobwhite populations are not yet answered and I will rely on studies with other species as necessary.

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TOXICITY TESTS

The first logical step in testing a pesticide for wildlife effects is to determine how much is lethal to one or more representative species (Turner 1981). EPA has issued standardized guidelines for such tests and the bobwhite is one of the species that may be used (Anon. 1978), reflecting many years of experience with this species as a test animal and the accumulation of a substantial data base that has been usefully summarized by Hill et al. (1975) and Kenaga (1979). Testing new chemicals during the research and development phase that precedes marketing now allows comparisons with pesticides already in use. The broad range of avian toxicities exhibited by OP and CA insecticides allows crude comparisons of potential acute hazards, but it does not provide one answer to the general question of whether these insecticides affect quail populations. That answer depends on the particular pesticide and the circumstances under which it is used.

Wildlife managers, as applied population biologists, also want to know whether insecticides depress reproductive rates. This is a more difficult question to answer because a bigger commitment of time and facilities is required for a reproductive study than for an acute toxicity study. Consequently, few bobwhite reproductive studies of OP's or CA's have been published. Coturnix quail (Coturnix coturnix) and ring-necked pheasants (Phasianus colchicus) have been used more frequently for these studies, and it appears that results with these species may be adequate guides for bobwhites. When I compared the reproductive responses of pheasants and bobwhites to diazinon, the species were qualitatively similar (Stromborg 1977, 1981). In both of those studies, egg laying was inhibited as a function of dietary dose during a three week trial. Although not exactly comparable, the results suggested that bobwhites were somewhat more sensitive to diazinon; the minimum dose that affected egg laying was lower as was the dose that completely blocked egg laying (Stromborg 1981). These reproductive effects were reversible and most birds resumed laying within several weeks after being taken off the pesticide diet. In addition, the hatchability of those eggs that were laid and the survivorship of chicks hatched from them was not affected.

A confounding variable was present in both of those studies that requires some explanation. When diazinon was added to their food, the birds ate less. This behavior is commonly seen in avian tests of highly toxic OP's and CA's, and several studies have demonstrated that caged birds will not eat large quantities of toxic feed if they have access to other foods (Hill 1972, Bennett and Prince 1981). What this means in the field is not clear, but it is known that some species do eat contaminated food under some circumstances (e.g., Mendelssohn and Paz 1977, Stromborg 1979, White et al. 1979). Reduced feeding rate due to pesticide-induced illness may be one of the effects of these insecticides under field conditions. This may lead to nutritional stress, but there is no evidence of any direct effect by these pesticides on energy metabolism (Watkins et al. 1978).

The diazinon tests with quail and pheasants also demonstrated a reduction in egg laying that was not explained by reduced feeding (Stromborg 1977, 1981). These effects may have been related to hormonal imbalances similar to those reported by Rattner et al. (1982 a) for quail fed parathion. EPA guidelines for registration require avian tests for reproductive effects under some circumstances (Anon. 1978), and, as in the toxicity testing requirements, bobwhites are a suggested test species. Therefore, data on reproduction should become available as these relatively new requirements are implemented. However, applying laboratory results to field conditions requires many assumptions about factors such as the availability of the pesticide over time, exposure of birds to it, and the interactions of pesticide effects with natural environmental stress (Rattner et al. 1982 b).

Behavioral alterations caused by OP and CA insecticides could reduce birds' ability to respond to environmental stresses. Kreitzer (unpublished data) found that extremely low dosages of several OP's lowered the ability of bobwhites to learn visual discrimination of shapes. What this means in a field context is unclear, but an alteration in learning ability might reduce the ability of quail to cope with a complex and varying environment. At higher doses, these chemicals influence behavior in evident ways that are symptomatic of severe poisoning. The toxic action of these chemicals on the nervous system produces uncoordinated muscular activity, prostration, regurgitation, and a variety of other signs all of which would interfere with a poisoned bird's ability to escape from potential predators. Poisoned songbird females temporarily abandoned incubation of clutches (Grue et al. 1982), and this might adversely affect embryonic development if it occurred during sensitive periods. All of these behavioral effects were produced by sub-lethal doses, so detecting their effects on a population under field conditions would require detailed studies and would not be apparent by cursory searches for evidence of poisoning in the form of dead birds.

EXPOSURE OF BIRDS IN THE FIELD

The principal question that must be addressed in attempting to apply laboratory results to field conditions is the extent of exposure, including both dose rates and duration. The usual method of establishing exposure of birds and other wildlife to OP and CA pesticides uses their effect on the enzymes collectively known as cholinesterases (ChE). In fact, the toxic effects of these pesticides are related to these enzyme effects; hence the pesticides are commonly referred to as anticholinesterases, or cholinesterase inhibitors. Applying accepted clinical practice from human medicine, Bunyan and Taylor (1966), in the first of a continuing series of studies, adapted biochemical techniques for quantifying the amount of enzyme inhibition in the brains of birds exposed to cholinesterase inhibitors. Ludke et al. (1975) and Hill and Fleming (1982) have given guidelines for interpreting field results of ChE measurements. At present it is thought that ChE inhibition reflects exposure to significant amounts of a ChE inhibiting pesticide, but some birds with severely depressed ChE recover although others die with less inhibition. As a diagnostic tool, ChE measurements are most useful in determining the nature of a chemical in dead birds. It is unfortunate that no precise predictive relationship between ChE inhibition and overt biological effects has been discovered. If such a relationship did exist and could be measured, interpretation of field results like the demonstration by Smithson and Sanders (1978) that wild quail had depressed ChE in areas sprayed with parathion might be extended to population effects by predictive modelling (Tipton et al. 1980).

In the absence of this relationship, it is necessary to determine the amount of exposure by more direct techniques if laboratory results are to be interpreted and used for predictive purposes. Quail are directly exposed to ChE inhibitors in a variety of ways. The most obvious is by eating seeds or vegetation treated directly with one of these pesticides. Several of these pesticides are effective seed treatments and have been applied to a variety of crop seeds. The rates of application are usually high enough to kill birds that eat more than a small number of treated seeds (Stromborg 1977). Unfortunately, intentional poisoning of granivorous birds is also easy and apparently not uncommon (Stone 1979). Although this source of exposure actually results from misuse (label statements include appropriate cautions about keeping wildlife and treated seed apart), under field conditions, there are often treated seeds available to birds after normal planting operations, and the rapidity of action of these chemicals localizes mortality so that even intentional poisonings may be undetected.

Vegetation that has been sprayed can also constitute a hazard to birds eating it. A number of instances of mortality, primarily of geese (<u>Branta canadensis</u>), have been recorded (Stone 1979). Wild turkeys (<u>Meleagris gallopavo</u>) have also been poisoned by feeding on vegetation sprayed with an OP (Nettles 1976). Both of these species are large and carcasses were usually found in the open; these factors combine to increase the probability of detection of poisoning. Similarly, reported die-offs of small birds are usually extensive (e.g., Seabloom et al. 1973) and consequently noticed by the public. In the absence of large conspicuous groups of casualties, detection of mortality may be infrequent (Rosene and Lay 1963).

A less easily studied route of exposure is secondary poisoning. Potentially, this could be extremely important to quail during the times that their diet is high in animal material (Rosene 1969:108, Hurst 1972). It is commonly believed that birds eat poisoned insects (Mills 1973, Stickel 1974) but few data exist on the amounts of ChE inhibitors such poisoned insects might contain. McEwen et al. (1972) found Guthion in grasshoppers during an operational grasshopper control program. Stromborg et al. (<u>In press</u>) found low residues of diazinon in an experimental application designed specifically to determine the feasibility of direct measurements of residues in insects. In another grasshopper control operation, biologically significant residues of acephate and its more toxic metabolite methamidophos were found (Stromborg, McEwen, and Lamont, unpublished data). Although these studies all demonstrate the feasibility of direct residue measurements, the practical difficulties of obtaining adequate samples have precluded widespread use of this technique. Direct demonstrations of secondary poisoning of birds by insects containing ChE inhibitors are equally rare, but White et al. (1979) reported mortality of adult and nestling laughing gulls (<u>Larus atricilla</u>) that ate parathion-poisoned insects. This route of exposure should receive much more attention in future studies, particularly the possibility that some ChE inhibitors may be metabolically transformed to more toxic substances in poisoned insects. This process can lead to erroneous interpretations of laboratory results where only the parent insecticide is tested.

In addition to these oral routes of exposure, bobwhites might be exposed through dermal contact if they occupy a sprayed area either during or after application. Hudson et al. (1979) tested a variety of ChE inhibitors for dermal toxicity in birds and concluded, as did Fowle (1972), that this is a potentially important route of exposure. Labisky (1975) tested this hypothesis with pheasants in a simulated application of a soil insecticide and observed some mortality and evidence of poisoning through dermal contact, but only under presumed worst-case conditions where he simulated a spill of the actual formulated product. During spraying, quail within a field might inhale significant amounts of insecticide. Berteau and Chiles (1978) compared the oral and inhalation routes in laboratory tests and concluded that there was little difference in toxicity between the two routes of exposure. Most probably, this is generally true of field exposures; the observed effect will be a result of total insecticide exposure from all of the potential routes: oral, dermal, and inhaled.

ECOLOGICAL EFFECTS

Although these direct poisoning effects are the usual focus of pesticide research with birds, under field conditions, the reduction of insect populations is probably also quite important to bobwhite populations. Field studies often result in reports of presumed emigration of birds from large spray blocks, but as McEwen et al. (1972:193) point out, emigrants probably rarely find suitable unoccupied habitat, and if they are actively nesting, emigration results in nest abandonment and loss of some reproductive potential. The impact of reduced insect populations is a function of the dependence of the quail on insects at the time of spray and the size of the spray block. If the sprayed areas are small and patchy, suitable foraging areas may be found close enough to the nest site that a simple shift in home range use may enable birds to find adequate insect foods without abandoning an active nest.

These direct and indirect factors acting simultaneously may constitute a serious potential hazard to populations of an agriculturally associated bird like the bobwhite. In fact, studies of organochlorine insecticides and quail clearly demonstrated severe impact on a regional bobwhite population (Rosene 1965). No such comprehensive study of ChE inhibiting insecticides has been undertaken with bobwhites. More field data for pheasants and ChE inhibitors are available than for bobwhites. Because these species are fairly similar in their food habits and agricultural association, it seems reasonable to expect that results from pheasant tests are applicable to bobwhites. Wolfe et al. (1971) exposed young pheasants in 5 acre pens to a simulated parathion spray and found that they ate large quantities of presumably poisoned insects shortly after the field was sprayed. Although ChE was depressed, they found no evident behavioral effects or mortality. In a similar test of young pheasants, Messick et al. (1974) found behavioral effects that would have increased their vulnerability to predators. Concurrent tests on unconfined wild adults indicated no apparent effects on survival or reproduction. The proportion of insects in the diets of wild juvenile pheasants in sprayed areas was drastically reduced when insect populations were reduced by pesticides. The significance of this reduction of an important protein source for growing birds is hard to assess. Potts (1977) found that when pesticides reduced the vital insect food sources of young partridges (Perdix perdix), the productivity of partridge populations was reduced. Considering the overall similarity of bobwhites and partridge in agricultural areas, it would be surprising if this was not also true for bobwhite populations.

There are many indications from both field and laboratory studies that ChE inhibiting insecticides might be influencing bobwhite populations. Some of these chemicals are extremely toxic to quail, and it is known that wild birds are exposed to biologically significant quantities under some conditions. Whether pesticide-induced mortality or reproductive effects depress bobwhite productivity is not known, and how these hypothetical limits might relate to other factors limiting populations through habitat destruction and degradation is not understood. We need to measure the actual exposure of bobwhites in the field to fully use the results of laboratory studies. We also need to determine whether other influences on mortality and reproduction compensate for pesticide effects. Ultimately, studies of these diverse influences on population dynamics will have to be integrated into a comprehensive study of this species if we want finally to assess pesticide effects on bobwhite populations.

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ADAPTATIONS OF FEMALE BOBWHITES TO ENERGY DEMANDS OF THE REPRODUCTIVE CYCLE[1]

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Abstract: The energy required by bobwhites (*Colinus virginianus*) to attain reproductive condition was measured for 30 individually caged game-farm raised birds. They were acclimated to an eight-hour photoperiod, which then was increased one hour each week until reaching 15 hours; it was then kept constant. One hen began laying eggs five weeks after the 15-hour photoperiod started. However, only 75 percent of the birds that eventually layed were laying after 12 weeks at 15 hours photoperiod. Average body weights increased from 194.2 g seven weeks prior to egg laying to 214.8 g while laying. Metabolized energy increased 24.4 percent (35.6 to 44.3 kcal/bird-day) during the six weeks prior to the onset of yolk deposition, which occurs in the week prior to laying. Metabolized energy increased another 18.3 percent to 52.4 kcal/bird-day while the quail were laying eggs. These results show several adaptations of bobwhites that permit them to meet the energy demanding activity of achieving reproductive status. This asynchronous response to photostimulation enables the birds to optimize their time of lay to unpredictable weather conditions prevalent in spring in temperate climates. In addition, the energy required to achieve reproductive condition is spread over six weeks; thus, the impact of increased energy demands is minimized.

Previous studies have quantified the energy requirements of egg-laying in bobwhites (Case 1972). However, energy demands to achieve reproductive status and energy requirements of incubation have not been reported. The objective of this paper is to quantify the energy requirements to achieve reproductive status. In addition I will discuss how bobwhites apparently cope with the enigma of an assumed short food supply during an energetically demanding period.

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METHODS

Thirty game-farm reared female bobwhites were individually caged under controlled photoperiod and a constant ambient temperature of 20 C. Food (chick starter, 21 percent protein and 4.2 kcal/g) and water were provided ad libitum.

Birds, feed, and excreta were weighed weekly. Approximately 0.5 hour prior to the onset of the photoperiod, feed and water were removed from the cages to ensure no ingestion of food or water immediately prior to weighing birds. Cages were cleaned and new feed was provided birds within 0.5 hour after the photoperiod started. Spilled feed and excreta (egested wastes plus nitrogenous wastes) were separated, then placed in individual petri dishes, and dried at 65 C for about 10 hours. Separation of feed and excreta was completed by sieving the mixture through a 10-mesh screen with gentle brushing. Separated feed and excreta were dried to a constant weight (usually 3 days). Birds, feed, and excreta were weighed to the nearest 0.1 g.

Feed and excreta were ground in a Wiley Model micro mill using a 20-mesh screen. Samples were weighed to the nearest 0.1 mg prior to calorimetric analysis in a Parr oxygen-bomb calorimeter.

Gross energy intake, excretory energy, metabolized energy, and existence energy, as defined by Cox (1961), were determined for each experimental bird. When birds maintained a constant body weight (± 1 percent or less of body weight during a week), metabolized energy was termed existence energy, that is, the energy to exist under caged conditions.

Quail were acclimated to an eight-hour photoperiod for four weeks. The photoperiod was

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then increased one hour each week until 15 hours. Photoperiod remained constant throughout the duration of the experiment. Nest boxes, provided with excelsior, were placed in each cage. The onset of weight gain was assumed to represent gonadal growth and attendant increased body fat associated with the birds becoming reproductively active.

A sample of birds was sacrificed at the end of the experiment. Oviducts and ovaries were weighed to the nearest 0.1 g immediately after removal so as to determine the differences between reproductive and nonreproductive birds.

RESULTS AND DISCUSSION

Twenty-four of the 30 experimental birds layed eggs. One hen commenced egg-laying five weeks after the 15-hour photoperiod began. However, it was not until 12 weeks after the onset of 15 hours light that 75 percent of the 24 egg-laying birds were laying eggs (Figure 1). Those results were unexpected for two reasons. First, since bobwhites start laying by 1 May in Kansas and Nebraska (Johnsgard 1979), it was anticipated that the threshold for photostimulation would be less than 15 hours. Second, regardless of a possible lower threshold for photostimulation, egg laying was expected to begin sooner than it did. Woodard et al. (1970) kept chukar partridge (Alectoris graeca chukar) on a short day, then increased the day length to 16 hours. First eggs were laid 21 or 22 days after photostimulation. A similar time is noted for domestic fowl to lay eggs following photostimulation.

Although the onset of egg laying was asynchronous among birds in this experiment, I assumed that the events leading to egg laying were time constant. Those events were manifest in increased body weights, which reflected proliferation of the reproductive tract and increased body fat. Thus, the event in common was egg laying. Body weights were averaged for each week preceding the start of egg laying (Figure 2).

Body weights averaged 194.2 g until seven weeks prior to egg laying. They then increased gradually, yet consistently, to an average 214.8 g. That weight is similar to the predicted body weights (216.2 g) of egg-laying bobwhites (Case and Robel 1974).

Metabolized energy was analyzed similarly to body weights. Metabolized energy averaged 35.6 kcal/bird-day through seven weeks prior to egg laying (Figure 3). Although metabolized energy appeared to increase eight weeks prior to the start of egg laying, seven weeks prior was chosen to be consistent with the data for body weights. Energy requirements for egg laying (52.4 kcal/bird-day) again were similar to 55.9 kcal/bird-day predicted by Case and Robel (1974).

King (1973) estimated the rapid phase growth (yolk deposition) of ovarian follicles for California quail (Lophortyx californicus) to be six to seven days. If this stage takes seven days for bobwhites, then the six preceding weeks represent the time to achieve full reproductive status. Average body weights increased 13.9 g over the six-week period. The average weight for the ovary and oviduct for nine reproductively active hens at the end of the experiment was 9.1 g. The average body weight increased only 6.7 g during the week prior to egg laying even though the average fresh weight of eggs was 8.7 g.

Over the six-week period metabolized energy increased an average 8.7 kcal/bird-day, which represents the requirement to achieve reproductive condition. The increase was 24.4 percent over existence energy requirements, yet

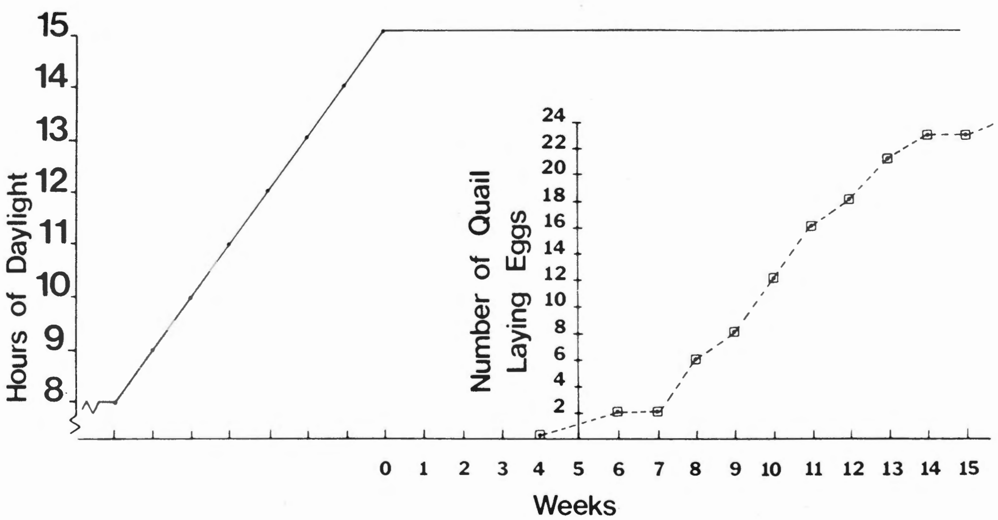

Fig. 1. Response time of quail to lay eggs following photostimulation.

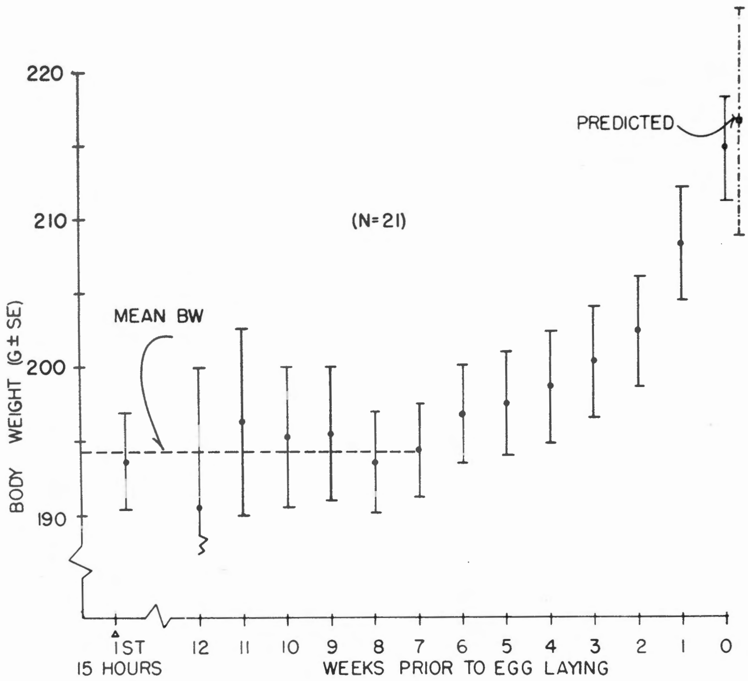

Fig. 2. Body weights of quail in response to photostimulation.

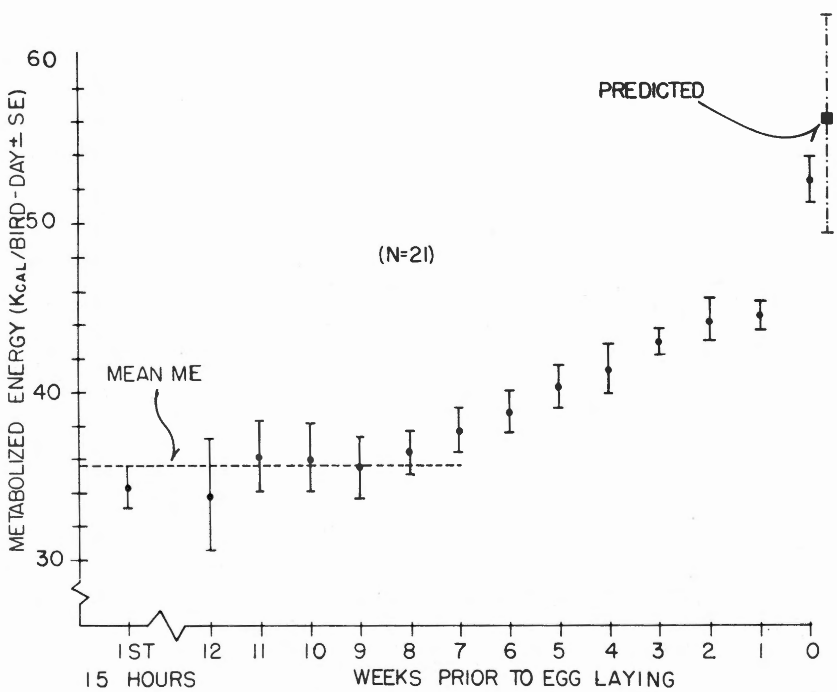

Fig. 3. Metabolized energy of quail in response to photostimulation.

on a daily basis, the increase was an average of only 0.85 kcal/bird-day. This increase does not reflect the energy cost for gonadal growth alone because body weight increased an average 13.9 g yet the average ovary and oviduct weight was only 9.1 g. Thus, the energy demand for gonadal growth is confounded with the energy requirement for adding fat. Metabolized energy in the week preceding egg laying averaged 8.1 kcal/bird-day more than the previous week, which represents an 18.3 percent increase.

Efficiency of egg laying was calculated as follows. During 645 bird-days 483 eggs were laid. The first five eggs for each bird were excluded in this analysis because they occurred at erratic intervals. The rate of laying was 0.75 egg/bird-day. Each 8.7 g egg would contain about 16.3 kcal (Case and Robel 1974). Metabolized (existence) energy for non-laying hens averaged 35.6 kcal/bird-day. The determined metabolized energy for egg laying was 52.4 kcal/bird-day, 16.8 kcal/bird-day greater than for existence. Then 12.2 kcal of egg (0.75 x 16.3 kcal) was formed each day at an additional energy expenditure of 16.8 kcal/bird-day, which represents 73 percent efficiency of egg formation.

ADAPTIVENESS OF BOBWHITES TO REPRODUCTIVE ENERGY DEMANDS

It is nearly axiomatic that bird populations wintering in temperate regions are limited by food during winter (Lack 1966, Hespenheide 1973). Indirect evidence for this phenomenon in bobwhites can be inferred from the low survival rates of juveniles from September to April (Robel 1965, Robel and Fretwell 1970) and the decreased body weights of bobwhites over winter (Kabat and Thompson 1963, Robel and Linderman 1966, Roseberry and Klimstra 1971). Rosene (1969) suggested that egg laying and incubating female bobwhites experience a greater physical strain than males and consequently may die faster because they are weaker. This conjecture may be supported by studies that demonstrate a nearly equal sex ratio of juvenile bobwhites but an adult sex ratio in favor of males (Leopold 1945, Kabat and Thompson 1963). The energy demands of egg laying alone do not appear excessive since they are equivalent to existence energy requirements at rather moderate winter temperatures of -3.3 C (Case 1972).

However, the additional energy demand of attaining reproductive status at the end of winter (24.4 percent increase over existence) may be stressful since this is occurring prior to egg laying when food may be scarce. There appear to be two distinct adaptations of bobwhites to cope with this apparent enigma. First, the increased energy required for the onset of reproduction is amortized over a six-week period so that the energy needs increase gradually. In fact, the most energy demanding stage (yolk deposition) is delayed until the week prior to the onset of egg laying when food is more likely to be abundant. This time requirement, which is much greater than that for chukar partridge and domestic fowl, apparently is not an artifact of using game-farm reared birds. Anthony (1970), in a field study, reported that growth of the ovary and oviduct in California quail began in late March and egg laying in early May. He found that recrudescence of the oviduct was 8 to 10 and the ovary 10 to 12 weeks. The second adaptation is the asynchronous response time of bobwhites to photostimulation. Although bobwhites may start egg laying by 1 May, the peak occurs in late May (Johnsgard 1979). The early layers would have a reproductive advantage over other birds when winters are mild or spring weather is favorable and possibly may raise two clutches (Stanford 1972). Late layers would have an advantage following severe winters or late spring. This strategy would optimize quail reproduction by following the adage of not putting all their eggs in one basket.

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REPRODUCTIVE SUCCESS AND BROOD SURVIVAL OF BOBWHITE QUAIL AS AFFECTED BY GRAZING PRACTICES

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Abstract: A radio telemetry study of 76 nesting and brood rearing bobwhite quail (Colinus virginianus texanus) hens was conducted during 1980 and 1981. Four study sites with different habitats and cattle grazing intensities were used. The 1980 breeding season was hot and droughty. Nine nests were found and three clutches of eggs hatched. There was a 1:3 adult to juvenile ratio in fall shot birds, and 66 percent hatched after 1 September following the rains of Hurricane Allen on 9 August. The 1981 breeding season was wet with average temperatures. One nest was found and seven broods were known to have hatched. Examination of quail wings showed a 1:5 adult to juvenile ratio, with 69 percent of the juvenile birds hatched prior to July 16, 9 percent in the latter half of July, 10 percent in August, 9 percent in September, and 2 percent in October. Seven unsuccessful nests were found. Five were destroyed by predators and two were abandoned. Chick mortality was 49 percent within the first two weeks of life in nine broods. Thirty-eight of 76 radio tagged hens were killed during the reproductive seasons. Reproductive success was highest during the wetter breeding season and highest in pastures that were moderately grazed and in good range condition.

South Texas bobwhite quail (Colinus virginianus texanus) populations are unstable. Wet years producing "bumper" crops of quail followed by a drought year may result in a low population. Variability in yearly population sizes is largely dependent upon land management practices and weather conditions affecting quail prior to and during the reproductive season (Lehmann 1946, Kiel 1976). Measurements of the reproductive capabilities of the bird have not accounted for the dramatic increase in population size during favorable years. It is difficult to get a true picture of summer population dynamics from data collected the following winter. The difficult parameters to measure are post hatching mortality rates and hen mortality. With the aid of radio telemetry, an intensive study of individual nesting and brooding hens was conducted during the 1980 and 1981 reproduction seasons. The specific objectives of this study were

(1) to determine reproductive success and chick survival of the bobwhite quail as related to grazing practices and land management;
(2) to determine habitats used by bobwhite hens for brood rearing;
(3) to determine the mortality rate of quail hens during the nesting season; and
(4) to document the occurrence of quail hens hatching a second brood.

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STUDY AREA

This study was conducted in Brooks County, located within the Rio Grande Plain resource region in south Texas, on the Miller and Mariposa Ranches, 1.25 km west and 4.35 km southeast of Falfurrias, respectively. The substrata of Brooks County is a sandy loam soil similar to many coastal counties of Texas. Soils are moderate to deep, up to 203 cm, and well drained. The topography is nearly level to moderately sloping.

The average annual temperature is 22.6 C; the climate is a warm, temperate, subtropical type with dry winters and hot humid summers. The average rainfall is about 61.3 cm, with extreme fluctuations between years. Rainfall records show variations from 22.7 cm in 1917 to a high of 140.0 cm in 1967. Of the years of recorded rainfall, 33 percent are shown to be droughty (Anonymous 1981). Occasional hurricanes, usually occurring in August or September, can deluge areas with 25.4 cm to 50.8 cm of rain in a matter of days, and spring and summer rains do not always occur (Kiel 1976).

Four pastures, i.e., Fruta, Justo, Rodeo, and Pita, with different vegetative composition and grazing histories were used as study sites. The Fruta pasture (568 ha) has sandy and loamy sand range sites, of an open grassland type, dominated by threeawns (Aristida spp.) and dotted with clumps of mesquite (Prosopis glandulosa) and granjeno (Celtis pallida). It has been continuously grazed by cattle since 1953 at a high stocking rate of 4.3 ha per animal unit and was in poor range condition. Range condition relates the current condition of the range to the potential of which the particular area is capable (Stoddart et al. 1975). Stocking rate is the area of land that the rancher allotted for each animal unit for the extent of the grazing period. A light stocking rate allows more hectares of grazing land per animal unit than a high stocking rate. An animal unit is the amount of forage needed to sustain a 1000 lb cow with a calf at her side for six months without a downward trend in range condition. The Justo pasture (1,380 ha) had a combination of sandy flat, sandy, and loamy sand range sites in low-fair range condition. Range sites were dominated by dense mesquite and mixed brush, threeawns, and gulf cordgrass (Spartina spartinae). The Justo pasture was rootplowed in 1975 but not raked. This pasture was continually grazed at a high stocking rate of 3.3 ha/au. The Rodeo pasture (1575 ha), a loamy sand range site, was once dominated by mixed, dense brush in poor range condition. Root-plowing, raking, and re-seeding to kleingrass (Panicum coloratum) in 1975 changed range condition from poor to good. Thirty percent of the brush was removed and the remaining 70 percent was left in random locations, clumps, drainage areas, and draws as cover for wildlife. This area has been moderately grazed at 6.5 ha/au in a continuous grazing system. The Pita pasture (894 ha) was a sandy hill range site in good condition. The plant community was an open grassland dotted with clumps of mesquite and live oak (Quercus virginiana). Tall and midgrasses were dominant and included little bluestem (Schizachyrium scoparium), indian grass (Sorghastrum nutans), and thinseed paspalum (Paspalum setaceum). Prior to May 1981 grazing was moderate at a stocking rate of 5.5 ha/au. In the summer and fall of 1981 the pasture was lightly grazed at 17.8 ha/au.

MATERIALS AND METHODS

Bobwhite quail were captured before the nesting season with Stoddard type quail traps (Wilbur 1967). An equal number of quail hens were caught on each study site, fitted with six g radio transmitters, and tracked daily. During the summer of 1980, 10 solar powered and 20 battery powered transmitters were used. In 1981 we used 30 solar powered transmitters. Telemetry equipment included a vehicle mounted, omni-directional, whip antenna; a directional three element hand held yagi antenna; and a portable 20 channel radio receiver. All locations of radio-tagged hens were plotted on aerial photographs of the study area to determine movements, ranges, and habitat preferences. When a nest of an instrumented hen was found, a detailed description of the nest, nest site, and surrounding vegetation was made.

Chick loss rates were determined by counting the chicks with each instrumented hen weekly or more often after hatching until combination of broods, or death of the hens or chicks made this determination impossible.

Brooding ranges were determined by the minimum area method (Mohr 1947). Estimates of ranges were determined only for those hens that were located on at least five different occasions.

Predators destroying quail nests and preying on radio tagged hens were identified from field sign left at the nest site or from carcass remains. Working transmitters from hens killed by predators were fitted on other hens to monitor a maximum number of birds throughout the reproductive season.

Bobwhite quail wings were obtained from hunters on the study areas for determination of adult to juvenile ratios and for back calculation of hatching dates of juvenile birds (Rosene 1969).

RESULTS

Reproductive Success

The 1980 breeding season was hot and droughty, with 4.4 cm of rain from January through April. The first substantial rainfall (5.0 cm) came on 8 May. Rains between 9 May and 8 August totalled 14.9 cm. Hurricane Allen, 9 August, dumped 32.5 cm of rainfall.

Forty-one hens were radio tagged in 1980; nine nests were found and three clutches of eggs hatched, 7 and 11 July and 24 September. Seven nests were found in June, one in July, none in August, and one in September. Quail wings obtained from hunting camps on the study areas showed a 1:3 adult to juvenile ratio. Thirty-four percent of the juvenile birds were over 150 days of age and hatched prior to mid-August. Back calculation of hatching dates for the remaining juveniles showed that 63 percent hatched in mid-September, and 3 percent in October. The September hatch followed the rains of Hurricane Allen on 9 August.

Five of 10 radio-tagged hens in the Rodeo pasture (moderately grazed, good range condition) nested, but only 1 of 14 radio-tagged hens nested in the Justo pasture (overgrazed, poor range condition). The Fruta pasture (overgrazed, poor range condition) had 3 birds nesting of 12 that were radio-tagged. No nests were found after Hurricane Allen due to loss of radio-tagged hens and failure of battery powered transmitters.

The 1981 breeding season was wet with average temperatures. Rainfall from January through September 1981 was well above normal with 2.6 cm recorded in February and 19.2 cm in August.

Thirty-five hens were radio-tagged in 1981. Only one nest was found because the solar powered transmitters failed to function while a hen was in dense cover, especially while a hen was sitting on a nest. Seven broods were known to have hatched; one in May, three in June, two in July, and one in August. The latest hatch was 7 August. Wings obtained from hunters showed a 1:5 adult to juvenile ratio. Sixty-nine percent of the juveniles were over 150 days of age and hatched prior to 16 July; 9 percent hatched in the latter half of July, 10 percent in August, 9 percent in September, and 2 percent in October. The latest bird hatched about 16 October.

The Rodeo pasture (good range condition) and the Justo pasture (poor range condition) were used as study sites in both years of the study. Twelve hens were monitored in the Rodeo pasture and two were found with broods. Ten hens were monitored in the Justo pasture and two were found with broods.

The Fruta pasture was not used as a study site in 1981. Only two hens were caught during four weeks of trapping this pasture. The pasture was apparently so overgrazed during the 1980 drought and the following winter that there was little nesting cover and the quail hens moved elsewhere during the spring covey break-up. The Pita pasture (lightly grazed, good condition) was added in 1981 to replace the Fruta pasture. Thirteen hens were radio tagged there and three broods were found.

Nests and Nest Losses

Eight nests of radio-tagged hens were found in which incubation of eggs had begun. Two other nests with eggs were found but were destroyed before they could be incubated. The eight complete clutches averaged 12.0 eggs and ranged from 9 to 18 eggs. One renesting effort was noted in which a hen's initial clutch had 15 eggs and her second clutch had nine eggs.

Forty eggs were found in three successful nests. Three eggs each in two of the successful nets were pipped, but ants (Solepopsis spp.) entered the eggs and killed the chicks.

Seven unsuccessful nests were noted. Five were destroyed by predators and two were abandoned. Field sign at the nest sites indicated that coyotes (Canis latrans) destroyed four nests and a skunk (Mephitis mephitis) destroyed another. Lehmann (1946) reported that most nest predation in south Texas was due to coyotes (80-83 percent), skunks (15 percent), and snakes (1 percent).

The two abandoned nests were in the early stages of incubation. One of the abandoned nests was a renesting attempt. Neither of the two hens attempted to renest after abandoning its nest. At the time of abandonment, there had been no rainfall for a month and maximum daytime temperatures averaged 37.4 C. Stoddard (1931) believed that few bobwhite nests are voluntarily abandoned, but abandonment may be due to some environmental disturbance. Klimstra (1950) noted that during periods of hot weather, incubating birds may abandon nests due to the excessive heat.

Chick Survival

During this study there was a 49 percent chick loss within the first two weeks of life. Data on chick mortality was collected from nine broods of radio-tagged hens during the summers of 1980 and 1981 . Chick loss rates were recorded for five broods from the date of hatch, two broods starting at two weeks of age, one brood starting at three weeks of age, and one brood starting at six weeks of age.

During the dry summer of 1980, two broods were observed from their dates of hatch. One brood of 10 chicks was lost entirely before two weeks of age; the remaining brood of 11 lost four chicks in two weeks and then only one chick up to 30 days of age, after which the hen was found dead and the location and fate of the brood could no longer be determined.

Seven broods were observed and followed during the summer of 1981. Three broods of 6, 12, and 16 chicks were lost within one week after hatching. The four other broods were from two to six weeks of age when observation began. After two weeks of age, chick loss was minimal with two chicks lost from one brood during its third week of life, and one chick lost per week after two weeks of age for the remaining three broods. Causes of chick loss were difficult to determine. Two broods, 12 and 16 chicks, were lost at three and five days, respectively. Both broods were in the Pita pasture (lightly grazed, good range condition), hatched during a period of heavy rains, and were lost during the same 24-hour period. Another brood, five days of age, was abandoned by the hen when she was flushed by the researcher.

Chick losses were higher in the Justo pasture (overgrazed, poor range condition) than in the Rodeo pasture (lightly grazed, good range condition) during both years of study. In the Justo pasture, one entire brood was lost within two weeks of age and two broods lost one or two chicks between two and four weeks of age. Three broods were tracked in the Rodeo pasture. One brood of 11 chicks had lost four chicks by two weeks of age and lost only one from then until 30 days of age. One brood lost one chick between six and seven weeks of age, and there was no chick loss from another brood between two weeks and 30 days of age.

Brood Rearing Habitat

Brood rearing habitat was determined for two broods in 1980 and seven broods in 1981. Cover used by brooding hens and chicks was dependent on the time of day. Most activity of hens with chicks occurred from about 0900-1100 hrs and 1500-1800 hrs. During these hours, hens led chicks into grassy, weedy areas of sparse to medium density with 15-70 percent bare ground. Areas too uniform in thickness (> 85 percent plant cover) were usually avoided.

Radio-tagged hens with chicks were found in protective cover from about 1100 hrs to 1500 hrs. This cover was usually a mesquite and mixed brush overstory, offering shade and protection, and an understory of short grasses, weeds, and debris with about 80 percent bare ground. Three brooding hens used the cover of large mesquite trees and granjeno surrounding natural ponds. Edges and breaks in vegetative pattern were very important. All radio locations of hens with broods were within 10 m of breaks in the vegetative pattern such as ranch roads and cattle trails. Activity patterns and the structure of brood rearing habitat were similar on all study areas. Brood ranges averaged about 0.8 ha.

Hen Mortality During the Nesting Season

Seventy-six quail hens were monitored during the study period and 38 mortalities noted. There were 44 percent and 57 percent losses of radio-tagged hens during the 1980 and 1981 seasons, respectively. Three hens died in May, 17 in June, five in July, eight in August, two in September, none in October, and one in November. Only one hen was known to have been incubating, and two hens had broods when they died. Predation was the major cause of hen mortality. Predators implicated by field sign and actual observations were coyotes (10), hawks (9), and Texas Indigo snake (1) (Drymarchon corias erebennus). One hen was killed when a tractor and mower ran over her, and another died from capture and handling stress. Twenty-eight hens were being monitored before Hurricane Allen. After its passage, five were found dead and five others had disappeared.

Second Broods

There was no evidence of second broods during the study period. Hens that lost their broods entirely did not nest again, and hens with broods were not found to leave them and nest again. Stanford (1972) documented 19 cases of second brood attempts in feral and penned wild bobwhites; of these, 14 were successful in hatching a second brood. Evidence of second broods in other species of quail has been found by Francis (1965) in California quail (Lophortyx californicus) and by Gullion (1956) in Gambel's quail (L. gambelli).

DISCUSSION

In south Texas, ranges almost devoid of quail in dry years have high populations during years of above average rainfall, providing that protective cover exists. The challenge for the manager is to be able to create habitat conditions such that huntable quail populations are produced during dryer years. Lehmann (1946) first pointed out that the keys to high quail reproduction in this area were rainfall and proper grazing management. His studies showed that quail preferred to nest in grasses nine inches tall or higher, which indicates range under light to moderate grazing activity. Our study indicates that pastures with a moderate level of cattle grazing have a higher number of birds nesting and better chick survival than overgrazed pastures in poor range conditions. Limitations of existing telemetry equipment handicapped data gathering especially for nesting studies. Battery powered transmitters lasted only 60-90 days and, therefore, did not span enough of the reproductive season to follow individual hens throughout; solar powered transmitters failed to function while birds were in deep shade, as when on a nest. The solar powered transmitters worked well in 1980 when cover was thin, but in 1981, higher rainfall produced denser nesting cover.

Kabat and Thompson (1963), Fatora et al. (1966), and Simpson (1976) found that quail chick mortality rates were highest within the first two weeks of life and then level off to about two to three percent per week into the fall. The present study bore this out and indicated that chick survival was better in pastures in good range condition than in those in poor conditions. Vagrancies of the weather still come into play, even in good brood habitat, as pointed out by the loss of chicks less than five days old during heavy rain showers.

In the present study, woody cover for shade and protection in close proximity to feeding areas was of paramount importance to broods. In addition, a high percentage of bare ground was essential for movements and feeding, as was the presence of trails and roads.

Mortality of hens during the reproductive season was high and may to some extent explain both the higher number of adult males than females in fall shot birds and the high numbers of juveniles per adult hen in fall shot birds. Kiel (1976) reported 10 to 14 young per female in south Texas and noted that such ratios could be attained by persistent renesting and high survival of young. Loss of adult hens would also contribute to a high ratio of young per adult hen.

CONCLUSIONS

Reproductive success of the bobwhite quail is dependent on the weather and man's management of rangeland. Quail in pastures that have light to moderate grazing pressures and are in good range condition have better reproductive success (numbers of hens nesting, successful nests, and higher chick survival) than do quail in pastures that are overgrazed and in poor range condition. High rainfall during the breeding season tends to offset somewhat the negative effects of overgrazing, but rainfall in south Texas is sporadic; management to offset drought conditions should be practiced at all times.

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STATE AGENCY PROGRAMS FOR BOBWHITE QUAIL MANAGEMENT ON PRIVATE LANDS

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Abstract: State programs to protect and improve wildlife habitat on private lands have characteristically provided indirect incentives including plant materials, signs, technical advice, and trespass control. Bobwhite quail have, no doubt, benefited from these programs although Wisconsin had the only project which specifically featured the species. The high level of participation in the Wisconsin endeavor suggested that certain cohorts of the private sector are willing to work cooperatively with land managers to improve wildlife resources. An interagency, comprehensive land management approach is needed. Wildlife habitat can be benefited by the improved management of soil, water, plant, and animal resources. Specific programs for quail habitat management on private lands will likely work best under a user-pays concept involving hunting recreation.

The principal range of the bobwhite quail (*Colinus virginianus*) is about 750 million acres (Johnsgard 1973:Fig. 39); approximately 87 percent of this acreage is rural lands under private ownership. The key to improved bobwhite habitat and increased hunting opportunity is a balanced program of incentives and education directed at the private landowner. State fish and wildlife agencies within the bobwhite's range have applied a variety of programs to improve the management of wildlife resources on private lands (Table 1). This paper will briefly describe the array of state projects, then discuss the efforts underway in Wisconsin, and finally outline the implications of these endeavors for future programs.

Wildlife management programs for private lands focus on (1) wildlife habitat protection and enhancement, or (2) access for recreational use of wildlife resources, usually hunting. The Acres for Wildlife program adopted by several states is an example of a wildlife habitat improvement program, and Pennsylvania's Cooperative Farm Game Program and Wisconsin's Project Respect are examples of access programs. Many programs link "habitat development" and "access for recreation" as typified by North Carolina's Gamelands Permit or Nebraska's Habitat Stamp.

Private-lands wildlife management is applied in two basic ways. Programs can be "targeted" at specific wildlife species or at protecting or enhancing particular habitat types. South Dakota's Pheasant Restoration Program is an example of a targeted or featured species approach. Conversely, projects may be "non-targeted" such as the Acres for Wildlife program, and the resultant habitat improvements or accessible lands are found in a shotgun-patterned distribution.

Programs to protect and improve wildlife habitat on private lands have been reviewed by Gottschalk (1977), McConnell (1977), Kuperberg (1978), Deknatel (1979), Madsen (1981) and Walton (1981). State programs characteristically provide indirect incentives--plant materials, signs, technical advice, and trespass control--to encourage the management of wildlife on private lands. Some form of aid for habitat development on private lands was provided by 44 states in 1979 (Deknatel 1979). Most state agencies within the bobwhite's range offer programs of potential benefit to quail, but only Wisconsin's pilot project appears to specifically feature the species.

STATE AGENCY PROGRAMS

Among the oldest and most successful state programs within the bobwhite's range are Pennyslvania's Cooperative Farm Game Program initiated in 1936 and North Carolina's habitat improvement project begun in 1946. Cooperators in Pennsylvania's program received personal property protection in return for public hunting rights for at least five years. Habitat improvement is encouraged, not required. By 1981, 18,967 landowners had enrolled nearly 2.3 million acres in the program (Horvath 1982). North Carolina's program provided 174,000 landowners with 870,000 units of plant materials from 1948-1976 (McConnell 1977). Periodic evaluations have shown good

Table 1. State fish and wildlife agency programs to improve the management of wildlife resources on private lands.[a]

State	Program	Source
Habitat Protection and Improvement[b]		
Arkansas	Acres for Wildlife	Ward and Pierce 1981
Georgia	Acres for Wildlife	Deknatel 1979
Illinois	Acres for Wildlife	Deknatel 1979
	Roadsides for Wildlife	Warner, in press
Indiana	Refuge Lease	Kirkpatrick 1977
	Classified Wildlife Habitat Act	Russell and Machan 1981
Iowa	Wildlife Habitat Stamp	George et al. 1981
Kansas	Acres for Wildlife	Deknatel 1979
	Wildlife Habitat Improvement	B. D. Hlavachick, KS FGC, pers. commun.[c]
Louisiana	Acres for Wildlife	Deknatel 1979
Minnesota	Property Tax Exemption	Peterson and Madsen 1981
	Operation Pheasant	Isley 1971
Missouri	Private Lands Program	Kirby et al. 1981
Nebraska	Acres for Wildlife	Cowgill 1971
	Habitat Stamp	Edwards 1981
North Carolina	RENEW	NC Wildl. Resour. Comm. 1977
Ohio	Habitat Planting Stock	Toepfer 1981
	Private Lands Wildl. Management	Toepfer 1981
Oklahoma	Acres for Wildlife	Deknatel 1979
South Carolina	Private Lands Wildlife Program	B. McTerr, SC, WMRD, pers. Commun.[c]
Tennessee	TWRA-TVA Cooperative Program	McConnell 1977
Texas	Tax Incentives	Walton 1981
Vermont	Wildlife Habitat Improvement	Sladyk and Regan 1981
West Virginia	Farm Game Program	R. L. Hall, WV, DNR, pers. commun.[c]
Wisconsin	Acres for Wildlife	Dumke and Frank 1982
	Quail Management Program	Dumke 1982
Access for Hunting Recreation[b]		
Maryland	Cooperative Management Area	Pane 1980
Michigan	Public Access Stamp	J. Urbain, MI, DNR, pers. commun.[c]
New Jersey	Operation Good Neighbor	Pane 1980
New York	Fish and Wildl. Management Act	Brown 1977
North Carolina	Game-lands Permit	McConnell 1977
Pennsylvania	Cooperative Farm Game Program	Deknatel 1979
	Safety Zone	Gottschalk 1977
	Forest Wildlife Cooperator	McConnell 1979
Rhode Island	Landowner Cooperative Project	M. L. Lapisky, RI, DNR, pers. commun.[c]
Texas	Shooting Preserve Law	McConnell 1977
Wisconsin	Project Respect	Dumke and Frank 1982

[a]All state fish and wildlife agencies within the bobwhite's range provide some degree of technical assistance.
[b]Primary thrust of the programs although other objectives may be involved.
[c]Information gathered via questionnaires to state fish and wildlife agencies.

compliance in the use of the planting stock for wildlife habitat improvement.

The primary thrust of Pennsylvania's Cooperative Farm Game Program is public access for hunting. Similar programs are offered by Maryland, New Jersey, New York, and Wisconsin with Maryland's program unique in providing litter removal in addition to the usual landowner services. More direct economic incentives for hunting access are provided by North Carolina's Game Lands Permit, which has opened 2 million acres to public hunting since 1971, and Michigan's Public Access Stamp.

Nebraska uses a portion of the revenue from a Habitat Stamp to protect and improve key habitats on private lands with a bonus if public hunting is allowed. In the initial fours years of this program, about 40,000 acres were enrolled under 1,800 contracts (Edwards 1981). The average payment for habitat improvement was about $18/acre. Iowa uses about $100,000/year from the sale of Wildlife Habitat Stamps to cost-share the establishment of switchgrass on private lands (George et al. 1981). This practice provides nesting cover for upland birds. Less direct economic assistance is offered under the Acres for Wildlife programs available in at least nine states within the bobwhite's range (Table 1). Typically, the state fish and wildlife agency provides coordination and technical assistance with co-sponsoring organizations and youth groups spearheading landowner enrollment. Participation usually requires protecting at least one acre for one year.

Ohio's ambitious Private Lands Wildlife Management Program was initiated in 1980 with a goal to acquire management control of 25 acres/mile^2 in 202 townships (Toepfer 1981). The Ohio Division of Wildlife's contribution to the interagency effort was $1.5 million in FY 1981 and $3 million was proposed for FY 1982. Six practices were available to provide nesting cover; cost-sharing for food patches was also offered.

States have also used leases, zoning, and tax incentives to preserve wildlife habitat and provide public hunting (Walton 1981). Indiana leased small plots (2-10 acres) as refuges for 10-year contracts during the period 1941-1959 and furnished plant materials for food and cover developments. Kirkpatrick (1977) discovered land use at 86 percent of the plots (n=43) favorable for wildlife production five years after the last lease had expired. Minnesota and Wisconsin use zoning to restrict development along waterways, and Wisconsin also employs a restrictive covenant to preserve agricultural and wildlife lands (Walton 1981). Forty-eight states have adopted farmland preservation measures, most employing preferential property-tax assessment (Council on Environmental Quality 1979), but the penalties for conversion have been questionably effective in preserving rural lands (Roe 1976). Minnesota and Indiana make property-tax exemption and credits available for the preservation of key habitat components. Texas offers tax incentives whereby agricultural and forest lands are taxed according to expected income and special exemptions are available to non-profit organizations holding wildlife lands (Walton 1981).

WISCONSIN PROGRAMS

Wisconsin is currently evaluating three wildlife management assistance programs for private lands with implications for bobwhite quail--Acres for Wildlife, Project Respect, and the Quail Management Program. The Acres for Wildlife program is an interagency effort involving the Department of Natural Resources (DNR), the Cooperative Extension Service, and the Department of Public Instruction. The primary objective of the program is to create an awareness of the need to consider wildlife when making land use decisions.

Informational brochures, 4-H project manuals, and free shrub packets are the only habitat management aids currently provided by the cooperating agencies. Participation in the program, as gauged by requests for materials, is low in the quail range. Enrollees are dedicating primarily non-cropland tracts already important as wildlife habitat. Although Acres for Wildlife is applied in a non-targeted manner, the program could be promoted by youth groups in selected areas to enhance food and cover relationships for a featured wildlife species, e.g., bobwhite quail.

The Project Respect program is designed to foster a better relationship between private landowners and hunters. The DNR supplies hunting permission forms, arm bands, and signs. Within the quail range, 181 farms encompassing 42,787 acres were enrolled from 1977-1979 for the primary purpose of controlling trespass associated with deer hunting. Quail hunters may have been given access to these lands prior to enrollment had they asked permission. Technical assistance and free plant materials for wildlife habitat improvement are offered under the Project Respect agreement, but few landowners request either. The program could be targeted at opening blocks of habitat to quail hunting, and the link between "access" and "habitat enchancement" could be strengthened at these sites.

The Quail Management Program has two objectives: (1) to double premanagement quail densities and stabilize population fluctuations, and (2) to develop incentive programs for wildlife management on private lands. Habitat restoration was the primary management thrust, and the practices were applied on a 60 mile^2 area in the heart of Wisconsin's quail range. DNR personnel representing wildlife, forestry, and research functions prepared management prescriptions in consultation with USDA county officials.

Between 1975 and 1980, 117 landowners were contacted to solicit participation in habitat development activities and 100 landowners (85 percent) ultimately participated in the program (Dumke 1982). This high level of cooperation exceeded the expectations of local resource managers and reflected an adequate incentive program and an effective delivery system. The key elements in this program that contributed to its success were (1) personal contact, (2) early support by community leaders, (3) flexibility in cooperative arrangements, (4) an acceptable agreement, and (5) interagency cooperation.

Personal contact was perhaps the most important factor in attaining a high level of cooperation in habitat improvement activities. Newsletters were used to introduce the program and provide progress reports to management area landowners (317 ownerships). Typically, three to four visits (about five hours) with the landowner were required to further outline the project and ultimately negotiate a satisfactory farm plan. These conversations were designed to gain an appreciation of the landowners' objectives for the property and the constraints that infringed on our cooperative management of the land.

A USDA report (U.S. Department of Agriculture 1976) emphasized the importance of interpersonal contacts in motivating farmers to adopt a particular management practice. Printed information promoted awareness in the predecision period, but adoption of a practice was enhanced by the presence of an information source that interfaced directly with the people involved. The report also indicated that the information source must be viewed as highly credible by the farmers. We found that biases caused by adverse press and previous experience can be overcome by restoring confidence through personal contact. Reinforcement of this confidence is accomplished by having a flexible working arrangement with potential cooperators and local support by community leaders and resource managers in other agencies.

Conversations between neighbors at social functions and at community gathering places were important in spreading the news of a "good" DNR project. We developed a good rapport with individuals whose opinions were viewed favorably in the community. The answers for questions regarding DNR's motives were available in the community, i.e., from neighbors and community leaders.

Flexibility was the key word in the approach used to solicit cooperators for habitat improvement activities. A signed agreement was the only common denominator; all arrangements were subject to negotiations. Our assumption was that a program that emphasizes flexibility may require more time during the negotiation process, but the level of cooperation will be greater and more sustained.

Habitat restoration activities of the Quail Management Program were designed to improve winter food and cover relationships for quail. Bobwhite quail were most abundant in Wisconsin during the mid-1800's when pioneering farming practices provided ample brushy cover and an abundance of waste grain for winter food (Kabat and Thompson 1963). The grazing of woodlands, more efficient harvesting of grains, and intensification of herbicide use resulted in the loss of critical food and cover components. The management strategy was to provide secure wintering sites connected by a network of continuous hedge.

Within the 60-section management area, 26 units of contiguous, physiographically similar habitat were identified. Traditional and potential wintering sites for quail were located and prescriptions written to improve food, cover, and dispersal features. The management units were prioritized for habitat development based on the potential for producing a continuous web of hedgerows encompassing at least three to four wintering sites. Within the high priority management units the landowners with key elements in the plan were contacted first. If the property owner(s) demonstrated an interest in the program, his (their) ideas were solicited and incorporated into a tentative plan. Subsequent negotiations produced a final farm plan and a 10-year agreement outlining the cooperative arrangement. Most often the property owners' contribution was the land devoted to wildlife production and DNR's contribution was the labor and materials for habitat improvement.

Over 465,000 shrubs and conifers were planted to create about 32 miles of new or improved hedge, six miles of enhanced riparian corridor, 11 miles of improved woodland edge, and 191 plots. The plots totaled 196 acres and varied from a clump of spruce covering about 1,400 ft^2 to a 6.7-acre unit with conifers, shrubs, brush piles, nesting cover, and food patches of legumes and sorghums. Sorghum food patches were planted on 75 plots; 13 of these sites had legume patches as an auxiliary food source for early winter. Sorghum patches were about 1/4 acre in size. The DNR cost of installing habitat improvements on the typical property was $1,600.

The target species for this program was the bobwhite quail; nonetheless, the promotional strategy featured the total wildlife benefits provided by the habitat improvements. Development costs could be charged to the production of the favored wildlife species, but the economic values are difficult to assign. The agreement developed for this pilot program does not require the cooperator to allow access for recreational use of the wildlife produced.

IMPLICATIONS

The high level of participation in the Quail Management Program suggests that certain cohorts of the private sector are willing to work cooperatively with land managers to improve our wildlife resources. The labor intensive approach used on the quail project was effective, but not practical for rangewide application. An interagency, comprehensive land management approach is needed. Wildlife habitat can be benefited by the improved management of soil, water, plant, and animal resources using a multi-purpose, integrated approach (Dumke et al. 1981:544, Karr 1981, McConnell 1981).

Federal programs, such as the SCS Small Watershed Program, provide the basic tools for better land management; what is needed is better leadership in all disciplines and at all levels (McConnell 1981). State fish and wildlife agencies should encourage interagency, multi-disciplinary work groups to explore improved private-lands management with wildlife values given equitable treatment. Wildlife resource advisory committees can provide the needed emphasis.

Specific programs for quail habitat management on private lands will likely work best under a user-pays concept involving hunting recreation.

State agencies should encourage landowner cooperatives or large corporate ownerships to practice habitat management for quail with benefits offered to hunter cooperatives or the hunting public on a fee basis.

The most successful programs will have provisions for dealing with important disincentives to program acceptance including control of access and hunter numbers, liability for injury, animal damage, and slow results from habitat developments. Economic incentives such as direct cash subsidies or tax exemptions and indirect benefits such as plant materials, birds for stocking, and technical advice will be required; personal and social incentives will also be present in the better programs (Svoboda 1980).

The impetus for new programs can originate from any sector and most often results from the persistent efforts of one individual. For example, the Minnesota property tax credits for wetland preservation resulted largely from the efforts of Carl Madsen with the U.S. Fish and Wildlife Service. State agency personnel (and other interested persons) must develop proposals and seek colleague and agency support, interagency endorsement, conservation organization interest, legislative action, and finally, public acceptance if we are to improve wildlife habitat on private lands.

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THE INFLUENCE OF LEASING UPON WILDLIFE MANAGEMENT AND HUNTING OPPORTUNITY

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Abstract: Leasing can stimulate better wildlife management on private land. Thus wildlife professionals should support leasing. Private landowners provide most hunting opportunity but receive a disproportionately small share of the revenue generated by hunting. Leasing is a just system that pays the person producing wildlife and charges the person using it. Leasing is not always detrimental to hunting opportunity. Considerations concerning the effect of leasing upon hunting opportunity are less important than considerations concerning the effect of leasing upon wildlife management.

Leasing of private land for hunting is a controversial topic among wildlife professionals; some actively support it, some passively accept it, and some aggressively oppose it. Here in Oklahoma, I have met several wildlife biologists who oppose the concept of leasing for hunting. It is unfortunate that wildlife professionals are divided on this issue. I believe leasing promotes better management of wildlife species that are deemed economically valuable, especially the game species. In an effort to reconcile these differences of opinion, this paper discusses the influence of leasing upon wildlife management and hunting opportunity.

I believe the fundamental relationships between leasing, wildlife management, and hunting opportunity are essentially the same for most game species. Therefore, much of the discussion in this presentation refers to game species in general instead of only bobwhite.

Leasing for hunting is a common form of the broader concept, recreational leasing. I define a recreational lease as an agreement between a property owner or manager and a sportsman whereby the right to participate in specified recreation on a specific tract of property is granted for a certain time and fee. The primary thing that is leased in such an agreement is the right to use the land for certain activities. Wildlife cannot be leased by a landowner because it is publicly owned by the citizens of a state.

The relationship between ownership of wildlife and control of it on private land is a paradox in our society. The public owns it, but individual landowners control it. Private landowners control wildlife populations because landowners control the existence and quality of wildlife habitats. Wildlife cannot exist naturally without proper habitat.

Most land in the United States is private land (Anon. 1958); therefore, the greatest potential for managing wildlife occurs on private land. One of the primary tasks of wildlife professionals should be to convince landowners that wildlife is a resource worth conserving and improving. To effectively sell this idea to landowners, wildlife professionals must recognize how society functions.

American society functions basically as a capitalistic economy. McConnell (1975) explains that capitalism is characterized by the following basic features: 1) private property, 2) freedom of enterprise and choice, 3) self-interest as the dominant motive, 4) competition, 5) reliance upon the price system, and 6) limited role of government. He further states that the price system is the basic coordinating mechanism of capitalism. In our society, the price system strongly influences the fate of resources. I believe recognizing this basic fact is an important step toward improving the future of wildlife on private land.

The aesthetic and ecological values of wildlife are more important to me than any economic or monetary value that could be assigned to it. However, I realize we do not live in a utopian society. We live and function in a capitalistic society where economic considerations direct the future of resources. We must use tools that our society responds to, such as money. Without tangible values for wildlife resources, I doubt we will change many landowner attitudes. The U.S. Fish and Wildlife Service has recognized the importance of assigning economic values to wildlife. In the 1975 National Survey of Hunting, Fishing and Wildlife-Associated Recreation (Fish and Wildlife Service 1977), tables and figures concerning expenditures of outdoor recreationists and economic values of various outdoor activities comprise about 18 percent of the data presented.

Leasing may somewhat bastardize a few wildlife resources, but without leasing, I fear habitat and corresponding wildlife will continue to disappear at a high rate in the future. Leasing can help reduce habitat loss and even encourage habitat improvements (Berryman 1957). So what is the lesser of the evils, leasing or habitat loss?

Wildlife competes with livestock, crops, and timber for space and food. If wildlife is viewed as a liability due to the inconvenience and damage caused by hunters, fishermen, trespassers, and wild animals, property owners will be inclined to destroy wildlife and its habitat. However, if property owners see their wildlife as an asset, since it can be a source of income, they will be encouraged to manage for it. If we expect landowners to sacrifice their time, labor, money, property, and agricultural production efficiency to produce wildlife, we should compensate them for their efforts. In my opinion, one of the best ways to reward landowners for producing wildlife is through recreational leasing.

Leasing will stimulate better wildlife management on private land (Burr 1930, Trippensee 1948, Howard and Longhurst 1956, Teer and Forrest 1969). When landowners receive income from a product of their land, they often develop the desire to further improve the resource. The situation in Texas supports this statement. Recreational leasing is probably better established in Texas than other states. I have met several private landowners in Texas who now hire wildlife biologists because they realize that better managed wildlife resources can mean better income.

Wildlife is a product of the land. Therefore, it follows that a landowner produces wildlife with his land. He owns and controls the habitat which allows the very existence of wildlife. Should not a landowner be compensated when people take his product? If hunters take it for free and cause him an inconvenience by their presence, what incentive does a landowner have to produce more wildlife? I have met some landowners who decided to destroy most of their game habitat to minimize trespassing and reduce hunter related property damage. The same landowners tell me they enjoy wildlife, but they cannot tolerate the problems its presence causes. If we expect landowners to produce wildlife for the public benefit, we should provide them an incentive.

The landowner is producing something that automatically belongs to someone else due to public ownership of wildlife. Yet, the public cannot hunt or observe this wildlife without also using his land. The landowner owns the habitat and the right to use the land. We should not expect him to give his rights away for nothing. I prefer to hunt for free, rather than pay, but I realize the landowner should get some return for providing game habitat for me to hunt in. Leasing provides a system for the person producing wildlife to get paid and the person using it to pay for it.

Leasing will increase the cost of hunting for some hunters, but it cannot be blamed for destroying free hunting. Hunting is not free now. Hunters must pay license fees, special excise taxes on sporting goods, special stamp fees (i.e., waterfowl stamps, bowhunting stamp, white-winged dove stamp, etc.), and public hunting area permit fees. These hunting fees are paid to state and federal agencies to perform research, gather biological data, make and enforce regulations, educate the public, and manage some public lands; however, they can produce only a limited amount of wildlife without cooperation from the private landowners. I feel a landowner is less likely to cooperate when he does not get a share of the funds.

According to the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, over $8.5 billion was spent on hunting expenditures in the United States in 1980, but less than 3.7 percent of this amount was spent for leasing hunting land, purchasing hunting land, and private land use fees. Yet, hunters pursued their sport on private land 68 percent of the days they hunted in the United States during 1980 (Fish and Wildlife Service and Bureau of the Census 1982). This national average includes all states, even those western states that have large acreages of public land available to sportsmen. Therefore, the people that produce a large percentage of the game animals and hunting opportunity get a small percentage of the income generated by wildlife and hunting.

It is fundamental that a resource must exist before it can be used. The primary responsibility of wildlife professionals should be to the wildlife resources (i.e., bobwhite populations and bobwhite habitat). Our responsibility to the users of wildlife resources (i.e., quail hunters and bird watchers) should always come second to this primary responsibility. Considerations about the effect of leasing upon hunting opportunity are important, but they are overshadowed by considerations concerning the effect of leasing upon wildlife resources.

Leasing is not as detrimental to hunting opportunity as many people imagine. Currently, most private landowners allow only limited access to their land for hunting in Oklahoma (Thorwardson 1979). A reduction in hunting opportunity caused by leasing (i.e., landowners who reduce hunter numbers to accommodate lessees) may be counteracted by landowners who open closed lands to lease hunting. I doubt leasing will decrease the total number of people hunting on private land. However, leasing will probably reapportion the hunting pressure; that is, individual lessees would not necessarily hunt on the same lands they hunted for free. Also, individual hunters may not have the opportunity to hunt on as many private lands as they did when hunting access was free.

Leasing may even provide more hunting opportunity than it suppresses. Leasing should help maintain game habitat; with leasing, there should be more quality places to hunt than there would be without it.

If all land became leased someday, it would reduce hunting opportunity--primarily because there is a finite quantity of land and a continually increasing number of hunters. However, as long as there are open public hunting lands available in our country, there will always be opportunity for hunting. In addition, I believe there will always be private lands which are not leased. There is a place in this country for public hunting land, private land leased for hunting, private land hunted for free, and private and public lands closed to hunting. This country can manage many diverse needs.

Some of my friends argue that leasing will make hunting too expensive for the average hunter. This would be true if all land became leased. But as long as there are public hunting lands, there will be inexpensive places to hunt. For this reason, I feel that recreational leasing must be restricted to private land. Also in accordance with our responsibility to hunters, wildlife biologists should support the use, maintenance, and increase of public hunting areas.

I agree that leasing may make many quality hunting places more expensive. However, without leasing, there will probably be less quality game habitat in the future and therefore fewer quality hunting places available. At least, leasing should give more hunters a choice of good quality hunting.

I believe leasing will benefit certain wildlife species more than others. The primary emphases of most hunting leases that I am familiar with in Texas and Oklahoma are white-tailed deer, bobwhite, or waterfowl. There also exist hunting leases which stress mule deer, pronghorn antelope, pheasant, turkey, mourning dove, fox squirrel, or other animals; but in my experience, these types of leases are not as common in Texas and Oklahoma. Since bobwhite is one of the "big three" mentioned above, the economic influence of leasing is likely to significantly benefit quail management.

Overall, this discussion explains that leasing can stimulate better wildlife management on private land. Leasing is not a panacea to our wildlife habitat problems (Hines 1953), but it is another tool we can use to maintain and improve wildlife habitat. To encourage more landowners to improve their wildlife management, we should encourage the pricing of wildlife resources on private land.

Leasing will evolve to satisfy the desires of the people involved with it. Wildlife professionals should become involved now during its early stages.

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A RADIO TRANSMITTER FOR QUAIL[1]

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Abstract: This paper describes a small radio-transmitter that has been developed specifically for use on quail. The transmitter weighs 5g, is disk-shaped (25mm diameter X 7mm thick) and is worn on the chest. It is kept in place by a harness made from nylon covered, stainless-steel wire that also functions as the antenna. Because of the transmitter's light weight, shape, and position, quail seem to tolerate it very well. Also, it cannot be seen by aerial predators. The nominal signal consists of 30 msec pulses with a frequency of 1 ha. Movement produces one extra 40 msec pulse per cycle, 500 msec after the 30 msec pulse. These characteristics allow for relatively simple automatic detection and recording of activity. The transmission range, using a commercially available 3-element Yagi and receiver, exceeds one-half mile. Life expectancy is about 60 days. Components for the transmitter cost about $25.00 (1981).

[1]Abstract only.

CLOSING REMARKS

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This Bobwhite Quail Symposium is primarily the product of one man's effort. Frank Schitoskey accepted the challenge of putting this meeting together and assumed the primary responsibility in the planning, organization, coordination, and editorial phases that made this symposium a reality.

In 1981, Dr. Schitoskey asked Tom Sanders, Elizabeth Schitoskey, and me to be members of the Steering Committee for the symposium. Subsequently, we determined the objectives of the symposium and selected several topics that we felt were particularly germane to bobwhite quail management in today's society. We felt that the problem of rapid deterioration of prime quail habitat had to be addressed. Likewise, an update was needed on the effects of disease, environmental toxicants, and harvest patterns on bobwhite populations. Manuscripts were solicited from several of you who are active in research in these areas. On behalf of the Steering Committee, we thank each of the authors of the solicited manuscripts for your time, your effort, and your professionalism. You have made a great contribution, not only to this meeting, but also to the profession of wildlife biology through your years of dedicated work.

We also want to thank the authors of the volunteered papers and those of you who participated in the panel discussion. These papers have rounded out the content of this symposium and addressed several issues that are currently the focus of research and management of bobwhite quail.

Besides those of you who submitted manuscripts, a number of other individuals contributed greatly to this meeting.

1. We are grateful to Bill Altman for chairing the Quail Hunters Field Events. He, with the help of a committee consisting of E. Epperson, John Floyd, Howard Jarrell, and Delmar Smith, planned and organized those events. We also thank Fred Oliver for serving as Master of Ceremonies, and we are indebted to each individual who participated in specific field events.

2. We thank our chairpersons, John Barclay, Scott Shalaway, John Skeen, and Elizabeth Schitoskey, for overseeing sections of the program. And we thank Billy Teals for serving as moderator of the panel discussion on public use of private land. Each of these people did an excellent job.

3. We are also indebted to Oklahoma State University for use of its facilities. In particular, we thank the Arts and Science Extension Office and the Student Union for their cooperation.

4. The Oklahoma Cooperative Wildlife Research Unit served as the host for this symposium, and we thank all Unit personnel involved. We especially thank Judy Gray for her enthusiastic assistance.

5. The Student Chapter of the Wildlife Society assisted in providing transportation for some of you to and from the airport. Those students who helped out in this capacity have our sincere thanks.

6. Finally, we thank the following sponsors for financial support:

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The papers presented over the last two days on bobwhite quail represent an overview of current research and management problems that are being addressed in the U.S. today. Dr. Klimstra presented an eloquent summation of the state of the art of bobwhite quail management and provided a great amount of food for thought. I hope each of us will reflect back on his comments from time to time. Dr. Klimstra pointed out the urgency of the present day situation. At one point in his presentation, he made the following comment:

"Examination of the literature on the bobwhite suggests that we have either considered, by in large, that there is no more to be learned about this important bird or we have, in general, given up hope that anything can be done to improve its status." A review of the last 30 years of the Journal of Wildlife Management certainly supports this statement. But is the literature a good indicator of the interests and goals of wildlife researchers? Probably not. I think wildlife researchers are as eager to study bobwhites as ever, but funding agencies across the country presently do not consider the bobwhite a high priority species. How do we convince administrators that bobwhites are high priority? I do not know the answer, but it must be done. We certainly do not believe there is no more to be learned about bobwhites. With destruction of habitat occurring on a daily basis and quail abundance decreasing in most parts of its range, there has never been more need for research on bobwhites than exists today. The specific areas that need additional research are overwhelming. As pointed out numerous times, there is a need to conduct research on local populations because we cannot necessarily use the results of research conducted on a population in one type of habitat for managing quail anywhere else where habitat, climate, and soil conditions are different. There does appear, however, to be a number of areas that deserve special consideration for future and continuing research that may have wide application throughout the species' range.

First, there is a need to develop low cost census methods that are sufficently sensitive to monitor small fluctuation in populations in local as well as regional areas. Without reliable, consistent, and accurate census methods, we cannot evaluate the effects of specific habitat manipulations or harvest methods. In the past, determining population trends was adequate in most cases. After all, we were all taught that in r-selected species such as quail, we did not have to worry about small fluctuations. If, however, we are to manage quail in a professional manner and avoid sometimes valid criticism by anti-hunting groups, we must be able to document the effects of specific management tactics. The work of Dimmick, Wells, Kellogg, and others should be helpful in this regard.

Second, there is a paucity of information on the reproductive ecology, particularly brood ecology, of bobwhite quail. A real need exists for research on the specific habitat requirements (not necessarily preferences but requirements) of quail broods in relation to habitat type, food, cover, and space. Survival patterns need to be studied in relation to specific habitat management practices. Innovative experiments need to be conducted to test specific hypotheses. Short term studies in so called "natural habitat" will provide baseline information from which hypotheses can be generated, but only long term studies that test multiple hypotheses will provide the information necessary for maximizing quail production on intensively managed public or private land.

Third, additional research is needed on the synergistic effects of environmental contaminants on quail survival and reproduction in natural habitat. As Stromberg pointed out, lab studies without application to field conditions provide little insight into the effects of sublethal doses of toxicants. Innovative experiments that involve both laboratory and field work could do much to elucidate the effects of low-level doses of contaminants, particularly pesticides and herbicides, on quail populations.

Fourth, the problem of compensatory vs. additive mortality of hunting needs further investigation. As Dr. Roseberry pointed out, hunting and non-hunting mortality are not completely compensatory. We need to know at what level of harvest does hunting mortality become additive and under what types of habitat and climatic conditions would we expect additive mortality to be most significant.

These are certainly not the only areas in need of research, but I think research in these areas would be sufficiently holistic to assure that results would have wide application throughout many parts of bobwhite range.

Another important topic discussed at this meeting was wildlife management on private land. This is a controversial topic and no easy solution appears in sight. However, quail will continue to decrease in abundance if solutions are not found.

One method suggested for enhancing, or at least maintaining, wildlife habitat on private land is providing a financial incentive to landowners for maintaining natural habitat. Much more information needs to be available to land owners in regard to cost-benefit ratios if these programs are to succeed in parts of this country. This type of information is not available for many areas. To provide such information, model farms that incorporate farming practices, ranching practices, and wildlife management into a profitable business are needed. These models could provide information on habitat management costs, wildlife and crop production, and total income derived from each operation. Such areas could be used for demonstration and extension education.

One specific financial incentive that may be attractive to some landowners and result in preservation of habitat is leasing land for hunting. The question and answer session of the Panel Discussion on Public Use of Private Land certainly demonstrated the controversial nature of this topic.

The controversy on the desirability of leasing as a method to preserve wildlife habitats stems, I think, from our failure to define our goals. If our sole goal is to provide more habitat for quail, then wildlife biologists cannot concern themselves with cost to hunters. If the price is within the reach of a sufficient number of hunters to make a leasing program cost effective, then it is an effective way to manage wildlife habitat.

If, however, our management goal is to provide recreation to the maximum number of hunters, then we must define success in a different way. These two separate but not mutually exclusive goals must be defined early in any program. During the panel discussion pertaining to leasing private land, the stated goal of the participants was to provide habitat for wildlife. They demonstrated that in some situations leasing of private land is a partial solution to preserving habitat. In other words, leasing works if the landowner can make a profit. The questions from the audience, however, quickly shifted towards an emphasis on hunter recreation. As far as I could determine, the objections were not because leasing provided quail habitat but because of the cost to the hunter. Therefore, we must define our goals. I am sure the topic of public use of private land will continue to be an important issue for many years. I suspect that as both the abundance and habitat of bobwhite quail continue to decrease due to agricultural practices, leasing in one form or another will gain acceptance in many parts of the country. Any hunting is better than no hunting to many quail hunters, and if leasing is the only alternative, many hunters will support leasing.

In conclusion, I think this symposium has come at a good time. We appear to be at one of the crossroads that occur from time to time in the wildlife profession when we do not know which way management is heading in this country. The continuing decline in funding for quail projects is affecting and will continue to affect the future of bobwhite quail, because fewer and fewer quail biologists are being produced by universities. This is occurring at a time when the need for energetic, innovative, and dedicated quail biologists is at its highest.

However, quail biologists have a duty to, as one oftens hears in political circles, "stay the course." The goal of our research should be to explain, not simply describe the responses of quail populations to habitat changes and management tactics. We should collect data that will allow us to test alternate hypotheses and, in general, make better use of the Scientific Method.